RDD:84:4096-05-01:01

2-9077

Babcock & Wilcox

FLUIDIZED-BED COMBUSTION OF COAL-WATER SLURRIES

RESEARCH AND DEVELOPMENT DIVISION
ALLIANCE RESEARCH CENTER

SPONSORED BY THE CANADIAN
DEPARTMENT OF SUPPLY AND SERVICES

MARCH 1984

"THIS REPORT WAS PREPARED AS AN ACCOUNT OF WORK SPONSORED BY A DEPARTMENT OF THE FEDERAL GOVERNMENT OF CANADA. NEITHER THE FEDERAL GOVERNMENT OF CANADA NOR ANY AGENCY THEREOF, NOR ANY CONTRACTOR OR SUBCONTRACTOR, NOR ANY OF THEIR EMPLOYEES, MAKES ANY WARRANTY, EXPRESSED OR IMPLIED, OR ASSUMES ANY LEGAL LIABILITY OR RESPONSIBILITY FOR ANY THIRD PARTY'S USE OF OR THE RESULTS OF SUCH USE OF ANY INFORMATION, APPARATUS, PRODUCT OR PROCESS DISCLOSED IN THIS REPORT, OR REPRESENTS THAT ITS USE BY SUCH THIRD PARTY WOULD NOT INFRINGE PRIVATELY OWNED RIGHTS."

FLUIDIZED-BED COMBUSTION OF COAL-WATER SLURRIES

Final Report by

Babcock & Wilcox
Research & Development Division
1562 Beeson St.
Alliance, Ohio 44601
(216) 821-9110

Principal Investigator:

D. R. Rowley

MARCH 1984

DEC 19 1984
MICROMEDIA

Work on this project was conducted under the auspices of the Canada Centre for Mineral and Energy Technology, Energy, Mines and Resources, Canada.

DSS FILE NUMBER	:	03SQ.23440-2-9077
DSS CONTRACT SERIAL NUMBER	:	0SQ82-00206
CANMET PROJECT NUMBER	:	430-704
CANMET SCIENTIFIC AUTHORITY	:	Ivan T. Lau

186pp

THE BABCOCK & WILCOX COMPANY
RESEARCH AND DEVELOPMENT DIVISION
ALLIANCE RESEARCH CENTER
ALLIANCE, OHIO

FLUIDIZED-BED COMBUSTION OF COAL-WATER SLURRIES

By: D. R. Rowley

PROJECT SUMMARY

PURPOSE

The primary objective of this project was to establish whether, considering the high moisture content and small particle size of coal-water slurry (CWS), stable and efficient combustion was attainable in a fluidized-bed combustor (FBC). If, indeed, stable combustion could be achieved, then parametric testing was to be carried out to determine the effect of varying operating parameters on performance. The performance characteristics to be measured included combustion efficiency, pollutant emissions, and the efficiency of sulfur capture. Operating parameters to be varied in the investigation included superficial gas velocity, bed temperature, calcium-to-sulfur ratio, bed height, and recycle of fly ash caught by the cyclone.

Also investigated was the feasibility of incinerating thickener underflow (coal tailings with a 70% moisture content) in a fluidized bed.

WORK SUMMARY

CWS testing was performed in the 1 x 1-foot FBC test facility at the Alliance Research Center. Three different slurry fuels were tested:

- Beneficiated coal-water slurry supplied by A B Carbogel of Sweden.
- Unbeneficiated coal-water slurry supplied by Scotia-Liquicoal of Nova Scotia, Canada.
- Thickener underflow from a coal-cleaning facility in Alberta, Canada.

RDD:84:4096-05:01
February 1983
Order No. 4096
B&W Contract No. CRD 1109
Fluidized-Bed Combustion, Coal-Water
  Slurry, 1 x 1-foot FBC Pilot, Alternative
  Boiler Fuels
Project Sponsored by the Canadian
  Department of Supply and Services

(Continued)

The first test series utilized the beneficiated Carbogel slurry. Ten test conditions were run for three hours of steady-state operation at each condition. The second series was for the unbeneficiated Scotia-Liquicoal fuel and consisted of nine test conditions. A third series of seven tests was planned for the thickener underflow, but due to a number of operational problems caused mainly by bed agglomeration, only one test was completed successfully.

The overall material balance and the carbon, sulfur, and calcium balances were calculated for each condition. Performance calculations were made, and a number of reasonable trends were observed over the range of variables tested.

RESULTS

From an operational viewpoint, the beneficiated Carbogel slurry (30% moisture) was the best of the three fuels tested. Combustion efficiencies for this test series were in the range of 92.5% - 98.2%; the highest combustion efficiency was obtained in the ash recycle test. The range attained for efficiency of sulfur capture was 18.8% - 66.1% for a calcium-to-sulfur ratio ranging from 1.0 to 2.9.

The unbeneficiated Scotia-Liquicoal slurry (40% moisture) required premixing (because of settling) before it could feed to the pilot unit, and the operation was less stable than for the Carbogel fuel. The range of combustion efficiencies was 92.2% - 97.6%, with the best efficiency occurring at the highest bed temperature (1731°F). Sulfur capture ranged from 48.4% - 94.1% for calcium-to-sulfur ratios of 1.0 - 4.9. The range of sulfur capture was generally much higher than that obtained with the Carbogel slurry. This can be attributed to a higher in-bed concentration of SO_2 (which is the driving force for SO_2 absorption) resulting from a higher sulfur content in the fuel.

Thickener underflow was burned successfully only when additional heat input was added (in the form of supplemental coal feed). Attempts to operate without auxiliary fuel resulted in severe agglomeration, which caused defluidization of the bed. Approximately one-third of the total thermal input was contributed by the coal feed.

CONCLUSIONS

This research effort was successful in demonstrating the feasibility of combusting a high-solids (60% - 70%) coal-water slurry and thickener underflow (30% solids) in a fluidized-bed combustor. Parametric testing revealed some good correlations between performance and various operating parameters that were, for the most part, in agreement with trends established through years of experience with fluidized-bed coal combustion.

(Continued)

Combustion

- Combustion efficiency was influenced by bed temperature and superficial gas velocity, although the data were scattered. The reasons for the scatter are not apparent from test data acquired in this program, but we speculate that the degree of agglomeration of slurry droplets in the bed has a significant effect on combustion.
- Recycle of cyclone fly ash resulted in improved combustion efficiency.
- Combustion efficiency was at least as good or better than that attained when firing bituminous coal under similar conditions in this test unit.

Sulfur Capture

- Increasing the calcium-to-sulfur feed ratio resulted in improved sulfur capture efficiency.
- The best sulfur capture was achieved while operating at a bed temperature of approximately 1550°F. Increasing the bed temperature had a detrimental effect on sulfur capture.
- Spent-bed lime utilization (30% - 40%) increased as the solid-retention time in the bed increased.

NO_x Emissions

- NO_x emissions increased with increasing bed temperature and decreasing CO emissions.
- An increased percentage of carbon in the carry-over resulted in reduced NO_x emissions.

Fluidized-bed combustion offers potential advantages over combusting coal-water slurry in a conventional burner. While fine atomization and optimum burner design are essential to achieving good combustion in a conventional system, they are not necessary in a fluidized-bed combustor. In fact, the method of injecting slurry into a fluidized bed is relatively simple, and combustion efficiency can be improved by operating at higher ash recycle rates than were tested in this program.

(Continued)

RECOMMENDATIONS

Favorable results obtained during this test program warrant further work in combustion of slurries in a fluidized bed. The following are four major areas that require further investigation:

- Agglomeration of slurry droplets in the bed. Because feed size has a significant effect on combustion, the feeding probe should be designed to produce an optimum droplet size. The optimum size of a droplet would result in the least amount of carbon lost to carryover. Different annular air velocities could be tested to determine their effect on droplet size.

- In some cases, because elutriated carbon loss is high, lower superficial velocities or a deeper bed should be considered to achieve better combustion efficiency.

- In fluidized-bed coal combustion, a major question in the design of large units is the number of feed locations needed to achieve good fuel distribution in the bed. From experience with firing fuel oil and very fine solid fuels, we feel that the number of feed locations required per unit area may be greater for slurry than for crushed coal. It will be necessary to quantify this if large coal-water slurry burning units are to be designed.

- Before an ambitious test program is undertaken to address these areas, a conceptual study of a commercial-scale, CWS-burning FBC is recommended to evaluate the economics of the system. For instance, there will be a trade-off between the additional cost of slurry preparation and the potential savings in coal transport expenses and possible simplification of the fuel feed system. (Pumping coal-water slurry may be less expensive than pneumatic transport of coal.) Also, in the case of thickener underflow, the initial capital cost and the operating cost of an FBC incinerator must be compared with present disposal expenses.

CONTENTS

Section		Page
1	INTRODUCTION	1-1
	Statement of Problem	1-1
	Program Objectives	1-3
	Work Scope	1-4
2	FACILITIES AND TEST PROCEDURE	2-1
	1 x 1-foot Fluidized-Bed-Combustion Test Unit	2-1
	Coal-Water-Slurry Feed System	2-5
	Gas Sampling System	2-8
	Test Procedure	2-9
3	RESULTS	3-1
	Fuel Characteristics	3-1
	Combustion Tests	3-6
	Heat Transfer Coefficients	3-16
4	DISCUSSION	4-1
	Carbogel Beneficiated Coal-Water Slurry -- Test Series 62	4-1
	Scotia-Liquicoal Unbeneficiated CWS -- Test Series 63	4-5
5	CONCLUSIONS AND RECOMMENDATIONS	5-1
6	REFERENCES	6-1

Appendix

A CHEMICAL ANALYSIS

B REDUCED PERFORMANCE DATA

C HEAT TRANSFER ANALYSIS FOR TEST SERIES 62 AND 63

ILLUSTRATIONS

Figure		Page
2-1	1 x 1-foot fluidized-bed combustion test facility	2-2
2-2	Bubble-cap fluidizing nozzle	2-3
2-3	FBC test unit process and instrumentation diagram	2-6
2-4	Coal-water-slurry supply system	2-7
2-5	Coal-water-slurry feed probe	2-7
2-6	Photograph of coal-water-slurry feed probe	2-8
2-7	1 x 1-foot FBC gas-sampling system	2-9
3-1	Carbogel beneficiated coal-water slurry, as received	3-3
3-2	Scotia-Liquicoal unbeneficiated coal-water slurry, as received	3-3
3-3	Scotia-Liquicoal unbeneficiated coal-water slurry, after one hour of mixing	3-4
3-4	Thickener underflow filter cake, as received	3-5
3-5	Thickener underflow slurry, 30% solids	3-6
3-6	Determination of ΔP_{plate}, ΔP_{bed} and bed height	3-8
3-7	Agglomerate formed during thickener underflow test, looking into furnace	3-14
3-8	Agglomerate formed during thickener underflow test on distributor plate	3-14
4-1	Effect of superficial gas velocity on combustion efficiency for Carbogel CWS	4-2
4-2	Effect of superficial gas velocity on CO emissions for Carbogel CWS	4-3
4-3	Percentage of carbon loss to cyclone outlet as a function of cyclone efficiency for Carbogel CWS	4-4
4-4	NO_x emissions as a function of bed temperature for Carbogel CWS	4-4
4-5	NO_x emissions versus CO emissions for Carbogel CWS	4-6
4-6	Effect of Ca/S ratio on sulfur capture for Carbogel CWS	4-6
4-7	Effect of bed temperature on sulfur capture for Carbogel CWS	4-7

ILLUSTRATIONS (Contd.)

Figure		Page
4-8	CO versus bed temperature for Scotia-Liquicoal CWS	4-7
4-9	CO as a function of superficial gas velocity for Scotia-Liquicoal CWS	4-8
4-10	Effect of bed temperature on combustion efficiency for Scotia-Liquicoal CWS	4-8
4-11	Effect of superficial gas velocity on combustion efficiency for Scotia-Liquicoal CWS	4-11
4-12	NO_x emissions versus bed temperature for Scotia-Liquicoal CWS	4-11
4-13	NO_x versus CO for Scotia-Liquicoal CWS	4-12
4-14	Effect of percentage of carbon in carry-over on NO_x emissions for Scotia-Liquicoal CWS.	4-12
4-15	Effect of Ca/S ratio on sulfur capture for Scotia-Liquicoal CWS	4-14
4-16	Effect of bed temperature on sulfur capture for Scotia-Liquicoal CWS	4-14
4-17	Spent-bed lime utilization as a function of in-bed solid-retention time for Scotia-Liquicoal CWS	4-15

TABLES

Table		Page
3-1	Analysis of composite samples	3-2
3-2	Operating conditions and test results	3-4
3-3	Carbon, sulfur, and moisture content measured at recirculation line outlet	3-10
3-4	Viscosity (cP) measured at approximately 100 sec^{-1} shear rate	3-11
3-5	Size analysis of limestone and sand bed material	3-11
3-6	Size analysis of ash streams	3-12
3-7	Heat transfer coefficient for in-bed tubes	3-16
4-1	Data comparison for Test Series 63 -- temperature variation	4-9
4-2	Improvement in combustion efficiency as a result of recycle	4-15
4-3	Percentage of temperature rise in freeboard	4-16

Section 1

INTRODUCTION

As part of a research and development program for evaluating coal-water slurry as a boiler fuel, Energy, Mines and Resources (EMR) of Canada explored fluidized-bed combustion (FBC) as an alternative to combustion in a conventional boiler. Also, FBC was examined as a potential incineration method for coal tailings (containing a high percentage of moisture and ash) produced by coal-cleaning operations practiced widely in Alberta and British Columbia.

This report describes pilot-scale testing done by the Babcock & Wilcox Co. (B&W) for EMR on a 1 x 1-foot FBC unit located at the B&W's Alliance (Ohio) Research Center (ARC).

STATEMENT OF PROBLEM

Incineration of Coal Tailings

To utilize lower-grade (high-ash, high-sulfur) coals in conventional pulverized-coal-fired boiler installations, it is attractive to beneficiate the coal to remove most of the ash and sulfur. Fuels with high ash contents can cause severe slagging in the furnace and fouling of the boiler tubes. Sulfur dioxide in flue gas formed during combustion of high-sulfur (4%+) fuels is environmentally unacceptable and expensive to remove with tail-end cleanup equipment. Therefore, in many cases, beneficiation becomes the most practical and economical technique for using lower-grade fuels.

The by-products of coal beneficiation processes include large quantities of combustible tailings. Some of these tailings, such as thickener underflow, are in a slurry form and contain as much as 70% moisture. This presents a disposal problem because of slow settling rates in sludge ponds and environmental constraints imposed on such ponds.

As an alternative to ponding the by-product sludge, incinerating the tailings in a fluidized-bed combustor could greatly reduce the total disposal problem. Because the moisture content of combustible tailings is so high, supplementary heat input could be required to sustain combustion. FBC is a potentially attractive method of incinerating tailings like thickener underflow, because low combustion temperatures (1500° - 1600°F) minimize slagging and fouling associated with fuel ash. Also, minimal fuel preparation would be required, since the thickener underflow could be pumped directly from the cleaning plant to the fluidized-bed incinerator. A potential problem could be the agglomeration of bed material caused by the high moisture content of the tailings.

Combustion of Coal-Water Slurries

Dwindling natural reserves and higher prices of oil and gas are prompting the need to develop techniques to effectively utilize abundant reserves of coal and other low-grade fuels. One method of coal use is to form a slurry with coal, water, and chemical surfactants and use the slurry as a substitute for oil and gas in existing boilers. Much effort is being directed toward developing and commercializing this technology.

One problem with burning a coal slurry in a boiler designed for oil or gas is the potential for fouling in the closely spaced steam generating tubes. A boiler designed for coal firing has a wider tube spacing to reduce the potential of ash deposits bridging between tubes. Therefore, to utilize coal-water slurry in an oil- or gas-designed boiler, the coal ash may need to be reduced by some beneficiation process before the slurry is made. Also, depending on the degree of beneficiation, boiler derating may be necessary. Additionally, the erosiveness of coal-water slurry has been shown to cause problems due to severe wear of burner atomizing nozzles.

It is well known that FBC has advantages over conventional combustion of pulverized fuel in its capability of handling the high ash content of lower-grade fossil fuels. Also, it is not necessary to achieve efficient (fine) atomization of CWS in a fluidized bed because of additional residence time in the combustion zone, as compared to conventional firing. Therefore, injecting the slurry into a fluidized bed should be much simpler than high-pressure air or steam atomization.

From an FBC standpoint, potential advantages of using slurry (as opposed to crushed coal) include reducing transport costs and possibly simplifying the system of feeding fuel. A significant percentage of the capital cost of a fluidized-bed boiler is in the coal and limestone preparation and feed systems. Pneumatic underbed feed systems require large amounts of high-pressure air and many feed locations for a large unit. Also, erosion of the feed lines becomes a severe problem. Pumping the fuel to the combustor in slurry form could offer an economic advantage over the pneumatic system and could also reduce erosion problems in the feed line. Transporting the slurry fuel via pipeline (rather than moving dry, crushed coal by truck or rail) could also be economically advantageous. Of course, these potential advantages would have to be weighed against the additional costs involved in producing the slurry itself.

OBJECTIVES OF PROGRAM

The primary objective of this research effort was to establish whether, considering the high moisture content and small particle size of coal-water slurries, stable and efficient combustion was attainable in a fluidized-bed combustor. If, indeed, stable combustion could be achieved, then parametric testing was to be carried out to determine the effect of varying operating parameters on performance. The performance characteristics to be measured included combustion efficiency, pollutant emissions, and the efficiency of sulfur capture. Operating parameters to be varied in the investigation included superficial gas velocity, bed temperature, calcium-to-sulfur ratio, bed height, and recycle of fly ash caught by the cyclone.

To pursue these objectives, three different slurry fuels were to be tested in B&W's 1 x 1-foot FBC unit:

- Beneficiated coal-water slurry supplied by A B Carbogel of Sweden.
- Unbeneficiated coal-water slurry supplied by Scotia-Liquicoal of Nova Scotia, Canada.
- Thickener underflow from a coal-cleaning facility in Alberta, Canada.

In the case of the thickener underflow, which contained 70% moisture, some form of supplementary heat input, either as preheated combustion air or auxiliary fuel, might be required to compensate for the high moisture content. An additional objective for the thickener underflow was to determine the minimum supplemental heat input required to maintain stable combustion.

WORK SCOPE

The testing portion of the project consisted of three test series. The first fuel tested was the beneficiated Carbogel slurry. A total of 10 test conditions were run for approximately three hours of steady-state operation at each condition. The second series utilized the unbeneficiated Scotia-Liquicoal slurry. Nine conditions were tested at three hours per condition. A third series of seven tests was planned for the thickener underflow, but due to a number of operational problems caused mainly by bed agglomeration, only one test was completed successfully. This test did require that a percentage of the total heat input be supplied by coal as an auxiliary fuel.

The carbon, sulfur, calcium and overall material balances were calculated for each condition. Performance calculations were made, and a number of reasonable trends were observed over the range of variables tested.

Test Limitations

Due to the relatively small scale at which these tests were run, the performance (that is, combustion efficiency and sulfur capture) of the pilot FBC might not give an absolute indication of the performance that could be expected on a commercial-scale facility. The trends observed should be consistent, regardless of scale. The following paragraphs detail some limitations of the testing performed on the pilot FBC.

Flow Rates of Solid Streams Leaving Unit. Ash streams leaving the combustor (cyclone, baghouse, and bed drain) are collected in drums and weighed. The weight of the material collected divided by the total time elapsed during the catch is the mass flow rate of that stream. For some of the conditions tested, the amount of ash collected was very small, resulting in poor resolution when weighing the catch. In some cases, the experimental error involved in weighing the sample contributed to a poor balance of calcium and sulfur. Also, bed material is drained from the unit batch-wise, resulting in step changes in bed height and bed pressure throughout the test. Therefore, the bed inventory changes with time, and the bed is not at a true steady state. When performing calculations for material balance, the bed inventory is assumed to be at steady state. Ultimately, this assumption is reasonable, as long as changes in bed inventory are small.

Gas Analysis. Measurements of flue gas (SO_2, NO_x, CO) were not taken on a continuous basis; rather, samples were collected every half hour and the results averaged over the steady-state time interval. Also, CO_2 was not measured, making it impossible to calculate a true carbon balance. Therefore, CO_2 was calculated by difference and carbon balances were forced. The calculated mass of CO_2 in the flue gas was converted to a volume percentage to determine if the calculated value seemed reasonable. Most tests had calculated values of 15% - 16% CO_2 (on a dry basis) in the flue gas, which is to be expected.

Fluctuations in Fuel Feed Rate. Throughout the test program, the slurry feed rate cycled approximately 5% - 10% from the setpoint rate. This was caused by cycling of the positive-displacement slurry feed pump.

Section 2

FACILITIES AND TEST PROCEDURE

1 x 1-FOOT FLUIDIZED-BED-COMBUSTION TEST UNIT

The B&W, pilot-scale, 1 x 1-foot, fluidized-bed combustor is depicted isometrically in Figure 2-1. This unit was designed specifically to provide lower-cost, fluidized-bed combustion (FBC) capability for testing alternative fuels and sorbents or new concepts. The flexibility of the unit, enabling major operating parameters such as bed temperature, gas velocity, bed depth, and air preheat temperature to be changed readily during operation, makes the facility highly suitable for performing screening tests.

The combustion furnace itself has an inside open area of 13-1/2 inches square and a brick-lined height of 16 feet. The furnace wall consists of 1/4-inch-thick steel, with insulating block and firebrick on the fire side. The hot combustion gases exit to an 18 x 18-inch x 2-foot-high unlined section before entering a 10-inch-diameter cyclone separator.

Fly ash collected by the cyclone separator can be discarded or conveyed to the furnace for reinjection. Material that is discarded is weighed on an intermittent basis so that a rate can be determined for performing a material balance. Downstream of the cyclone separator, particulate carried over from the cyclone enters the baghouse, where it is caught and weighed.

Combustion air is supplied to the system by a forced-draft (FD) blower. Therefore, the entire system is operated at a pressure slightly above atmospheric. Ambient air from the FD fan enters a steel windbox, internally lined with insulation, where it is preheated to the desired temperature by a natural-gas burner. Preheated fluidizing air enters the combustor and is uniformly distributed through a bubble-cap distributor plate. The plate consists of 39, 1/4-inch, Schedule 40, stainless steel pipes approximately 5 inches long, threaded into a 1/2-inch steel plate. A single bubble-cap fluidizing nozzle is shown in Figure 2-2. The base plate is protected by a 4-inch layer of cast insulation.

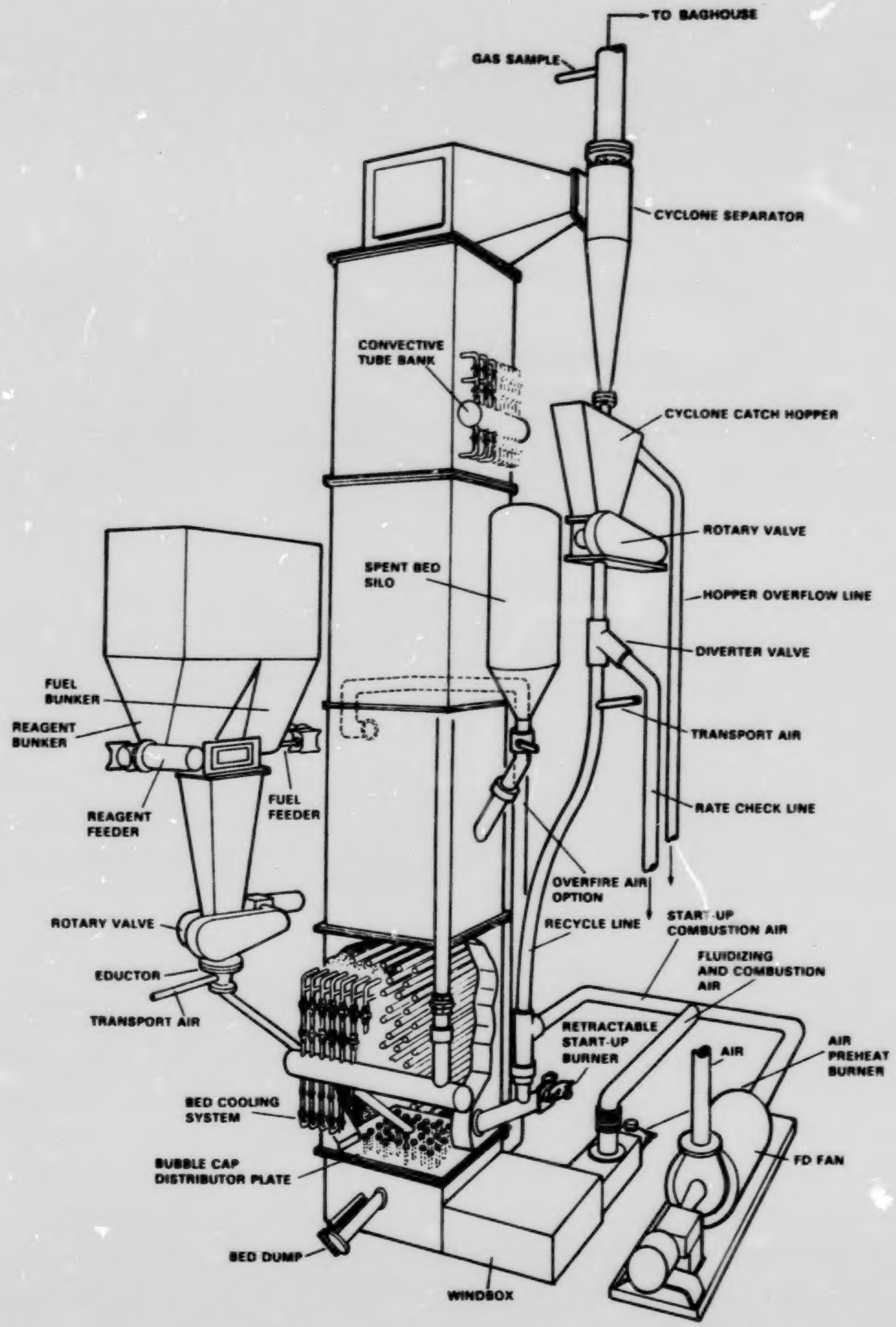


Figure 2-1. 1 x 1-foot fluidized-bed combustion test facility.

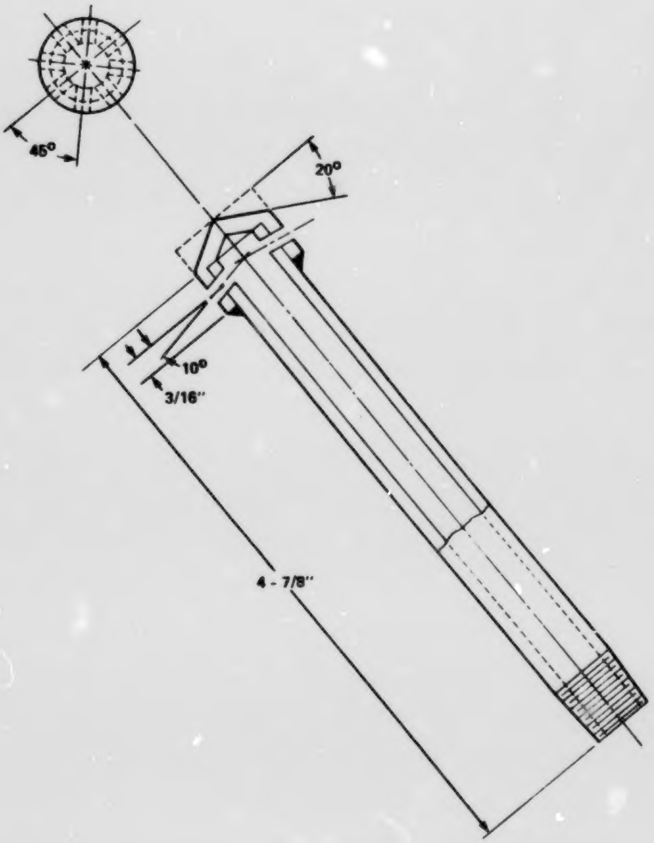


Figure 2-2. Bubble-cap fluidizing nozzle.

The combustion zone is preheated by a gas burner before introducing solid or slurry fuels to the unit. The feed rates of solids (fuel or limestone) entering the furnace are controlled by variable-speed screw feeders located at the bottom of each of two, 10-cubic-foot-capacity storage hoppers. The solids leaving the screws discharge into a rotary feeder that seals the feed system against furnace pressure. From the rotary valve, the solids enter a flow eductor, where they are picked up pneumatically and transported to the furnace. The transport line leaving the eductor is 1-inch, Schedule 40 pipe approximately 4 feet long. The material exits the transport line through a single-center feedpoint located 2 inches above the distributor plate.

Heat extraction from the bed is accomplished by controlled flow to any or all of 27 water-cooled tubes. This arrangement is designed to accommodate up to 63, 3/4-inch, Schedule 40 pipes with provisions to employ any desired tube arrangement over a height of 10 inches to 48 inches above the air distributor. Individual tubes can be readily added or removed, since each is connected separately to a common header. Plant water flows through the tubes and is discharged by gravity into a collection trough. Each tube is independently valved to permit readily changing the in-bed heat transfer surface area, therefore changing the bed temperature, during operation. Cooling-water flow to the in-bed cooling surface is metered, and the water inlet and outlet temperatures are monitored so that in-bed heat transfer coefficients can be determined.

A convective tube bank is located near the top of the furnace section. The design is the same as the in-bed tube bank, except that the convective section is comprised of 40 tubes. Gases are cooled in the convective section to protect the uninsulated cyclone separator. Further cooling is accomplished downstream of the cyclone by diluting the hot gases with ambient air. This additional cooling is needed to maintain gas temperature below that which can be tolerated by the Nomex bags in the baghouse (400°F).

Samples of combustion gases are taken at the stack. The gas is analyzed on line for determination of SO_2, NO_x, O_2, and CO. Samples taken are transported at 300°F from the stack to analyzers located in a separate room.

The pilot-scale unit is instrumented for numerous pressure and temperature measurements. These are depicted on the process and instrumentation diagram of Figure 2-3. Also shown in Figure 2-3 are flow orifices and the arrangement of the in-bed and convective tube banks.

COAL-WATER-SLURRY FEED SYSTEM

The system used to transport slurry to the pilot-scale unit is depicted in Figure 2-4. Slurry is stored in a 500-gallon tank that feeds into a variable-speed, positive-displacement, Moyno pump. The piping arrangement allows fuel to be pumped to one of two units: the 1 x 1-foot unit or the basic combustion test unit (BCTU), which is used for pilot-scale burner studies.

From the outlet of the pump, the slurry flows through a 1-inch, Schedule 80 pipe to the test unit. Because the pump capacity was much greater than needed to supply the required flow rate, a recirculation line (3/4-inch, Schedule 80 pipe) was installed to return the excess slurry back to the storage tank. Varying the pump speed allowed some control of the flow rate, but more precise control was accomplished by varying the amount of recirculation. This was done by throttling the valve on the return line. (To increase flow to the unit, the valve is closed; to decrease flow, the valve is opened.)

The slurry feed rate was measured downstream of the recirculation line so that the measured rate was the amount that went to the unit. The flow rate was read out directly in lbs/hr using a Micromotion Model C25 mass flow meter. A short length of flexible hose connected the meter outlet to the inlet of the feeding probe.

The slurry-feeding probe is shown schematically in Figure 2-5 and photographically in Figure 2-6. Slurry was fed through an open-ended, 1/4-inch, stainless steel tube surrounded by an annular airstream that aided in dispersing the slurry at the point of injection. The location at which slurry entered the bed was 5 inches above the air distributor and 1/2 to 1 inch into the bed from the west wall of the unit. The probe was water-jacketed for cooling.

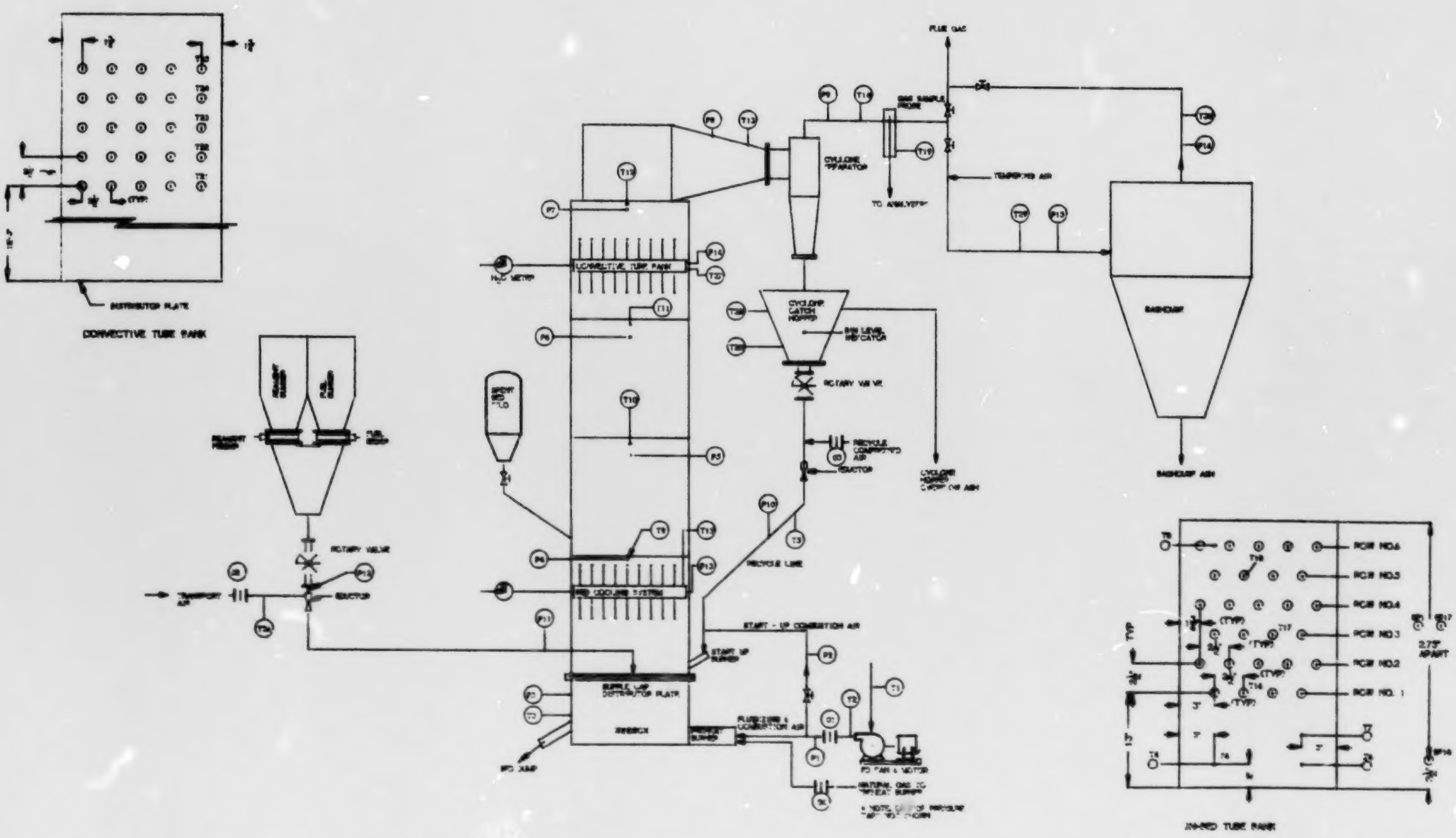


Figure 2-3. FBC test unit process and instrumentation diagram.

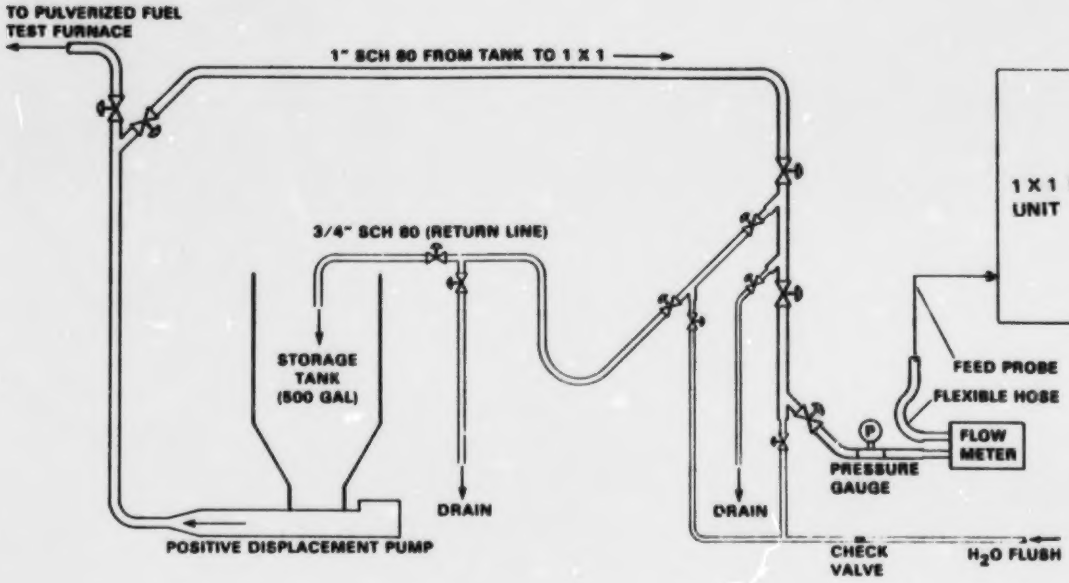


Figure 2-4. Coal-water-slurry supply system.

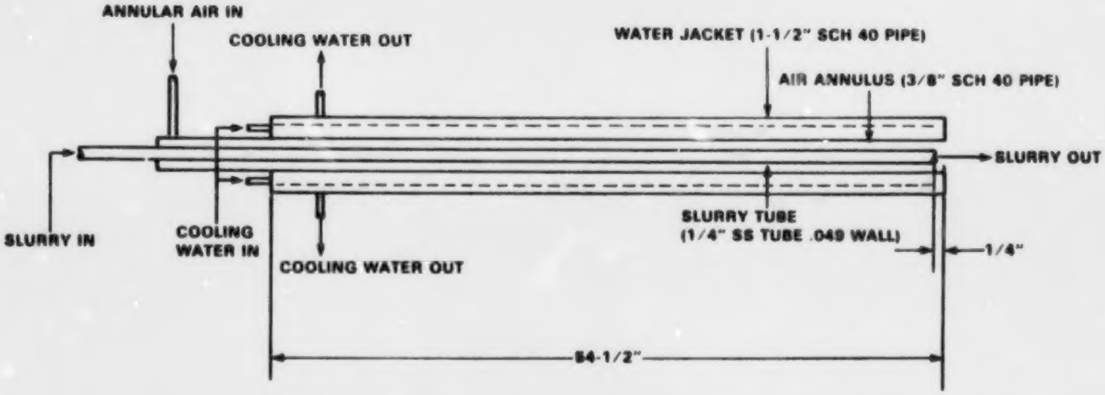

ANNULAR AIR IN
COOLING WATER OUT
WATER JACKET (1-1/2" SCH 40 PIPE)
AIR ANNULUS (3/8" SCH 40 PIPE)
SLURRY OUT
SLURRY IN
COOLING WATER IN
COOLING WATER OUT
SLURRY TUBE (1/4" SS TUBE .049 WALL)
1/4"
54-1/2"

Figure 2-5. Coal-water-slurry feed probe.

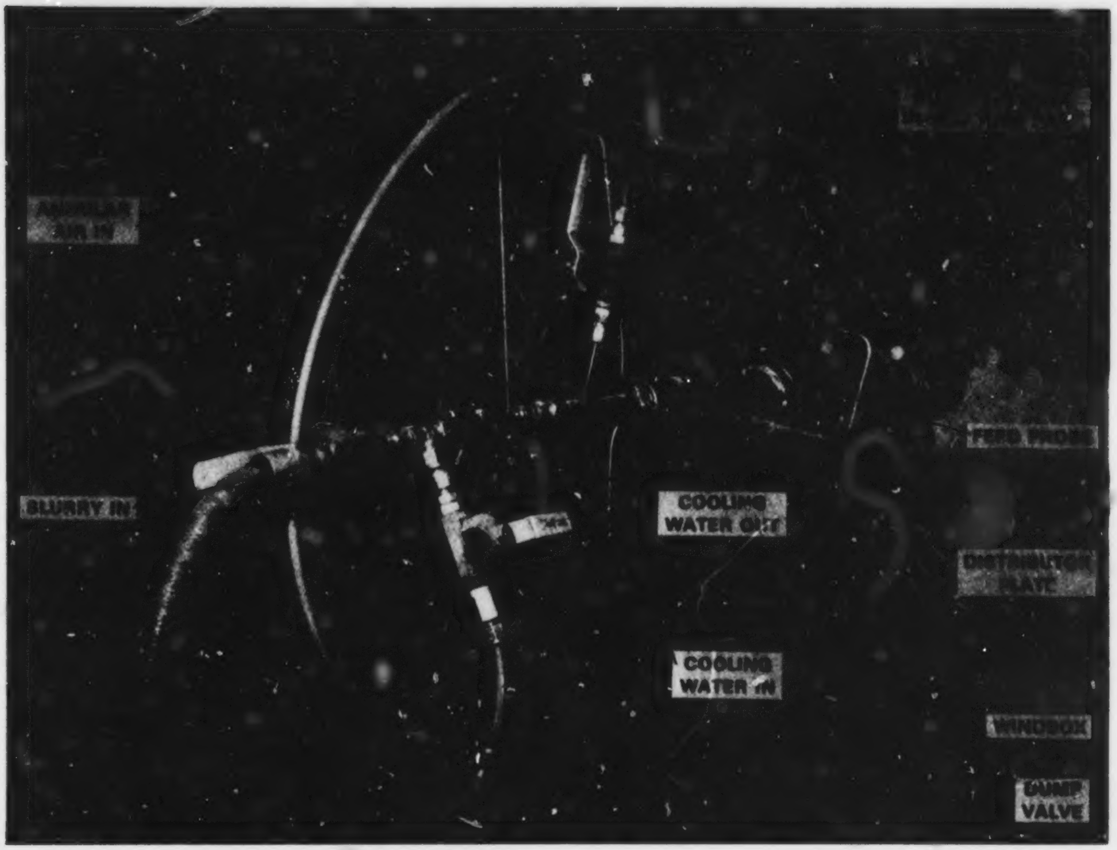


Figure 2-6. Photograph of coal-water-slurry feed probe.

GAS-SAMPLING SYSTEM

The gas-sampling system is shown schematically in Figure 2-7. The instrumentation used to obtain on-line flue gas analysis was as follows:

Gas Species	Instrument
O_2	Bailey (Catalytic Combustion) Teledyne (Fuel Cell)
SO_2	Dupont 459 (UV)
$NO-NO_x$	Thermoelectron 10 (Chemiluminescence)
CO	Beckman 864 (IR)

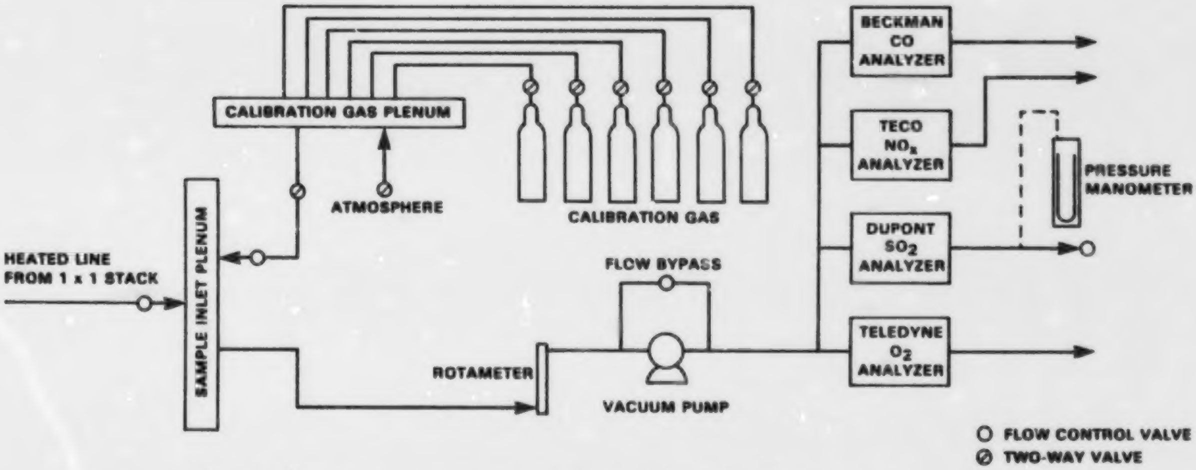


Figure 2-7. 1 x 1-foot FBC gas-sampling system.

TEST PROCEDURE

Startup

A bituminous coal was used as startup fuel throughout the test program. After lighting off on coal with a very shallow bed, inert bed material (sulfated limestone) was fed through an overbed port until the desired bed height was reached. Once bed inventory was established, limestone feed was initiated. During the startup procedure, air was introduced through the slurry tube and the annular air tube of the feed probe to prevent probe plugging.

When desired bed temperature was attained, a transition from coal feed to slurry feed was made. The probe air was then diverted entirely to the annulus. For the beneficiated (Series 62) and the unbeneficiated (Series 63) slurry tests, the transition was essentially a step change. The thickener underflow test (Series 64) required a more gradual transition due to potential agglomeration and defluidization caused by the high moisture content (70% by weight) of the fuel. After the slurry feed had steadied out, if the bed temperature deviated from the planned value, the in-bed cooling surface was adjusted until the desired temperature was reached.

Data Collection

When steady operational conditions were attained (stable bed temperature and outlet SO_2), a rigid data acquisition schedule was followed. All operating data (pressures, temperatures, and flows) and gas analysis were recorded every 30 minutes. Cyclone ash samples were taken and the catch was weighed hourly. The baghouse was cleaned when necessary to maintain a pressure drop across the bags that would not cause excessive back-pressure on the balance of the system. A baghouse ash sample was collected and the catch was weighed at each test condition. Bed material was drained periodically to maintain a relatively constant bed inventory, and a bed sample was collected for each condition. The gas analyzers were calibrated at the beginning and end of each test.

Section 3

RESULTS

FUEL CHARACTERISTICS

The chemical analysis, mean particle size, and viscosity of composite samples of the three fuels tested are given in Table 3-1. The Carbogel beneficiated slurry was shipped to B&W in one-cubic-meter containers. Figure 3-1 shows the physical appearance of the fuel upon receipt. This slurry was fired in the pilot unit as received, requiring no additional preparation.

The Scotia-Liquicoal unbeneficiated slurry was shipped in 55-gallon barrels and appeared much different than the Carbogel fuel. Figure 3-2 depicts how the slurry appeared upon shipment. The Scotia-Liquicoal fuel required premixing before it could be pumped and fed to the unit. Before testing, each barrel of the fuel had to be mixed for 45 to 60 minutes in an end-over-end barrel tumbler. The slurry is shown in Figure 3-3 as it appeared after one hour of mixing.

Not only were the chemical analysis (Table 3-2) and physical appearance of the Carbogel and Scotia-Liquicoal slurries different, the viscosities of the two fuels were also quite different (Table 3-1). Plotting shear stress versus shear rate for the unbeneficiated fuel (Appendix A) indicates that this fuel exhibits a behavior that is characteristic of a Bingham plastic fluid. The beneficiated slurry did not show the same relationship. The curves for shear stress versus shear rate in Appendix A indicate that the Carbogel beneficiated slurry represents a pseudoplastic fluid. Further investigation of the transport properties of the slurries was not an objective of this program. Neither of the two slurries presented problems from the standpoint of pumping or transportation, although some ball valves in the feed system control loop were severely worn due to erosion.

Table 3-1

ANALYSIS OF COMPOSITE SAMPLES

	Carbogel Beneficiated Slurry	Scotia-Liquicoal Unbeneficiated Slurry	Thickener Underflow
Proximate Analysis %			
Moisture	28.51	41.00	69.40
Volatile Matter	26.12	21.65	8.84
Fixed Carbon	44.32	28.62	6.64
Ash	1.05	8.73	15.1
Gross Heating Value, Btu/lb	10890	6970	1650
Ultimate Analysis, %			
Moisture	28.51	41.00	69.4
Carbon	60.94	39.88	11.5
Hydrogen	3.98	2.51	0.69
Nitrogen	1.15	0.62	0.15
Sulfur	0.50	3.44	0.07
Ash	1.05	8.73	15.1
Oxygen	3.87	3.82	3.09
Calcium in Ash as % CaO	2.22	6.46	3.81
Mass Mean Diameter*	56.41	37.43	66.60
Sauter Mean Diameter*	8.02	5.90	4.70
Viscosity (cP @ 100 sec^{-1})	1317 - 1467	688 - 1187	19 - 32

---

* Micrometer

Figure 3-1. Carbogel beneficiated coal-water slurry, as received.

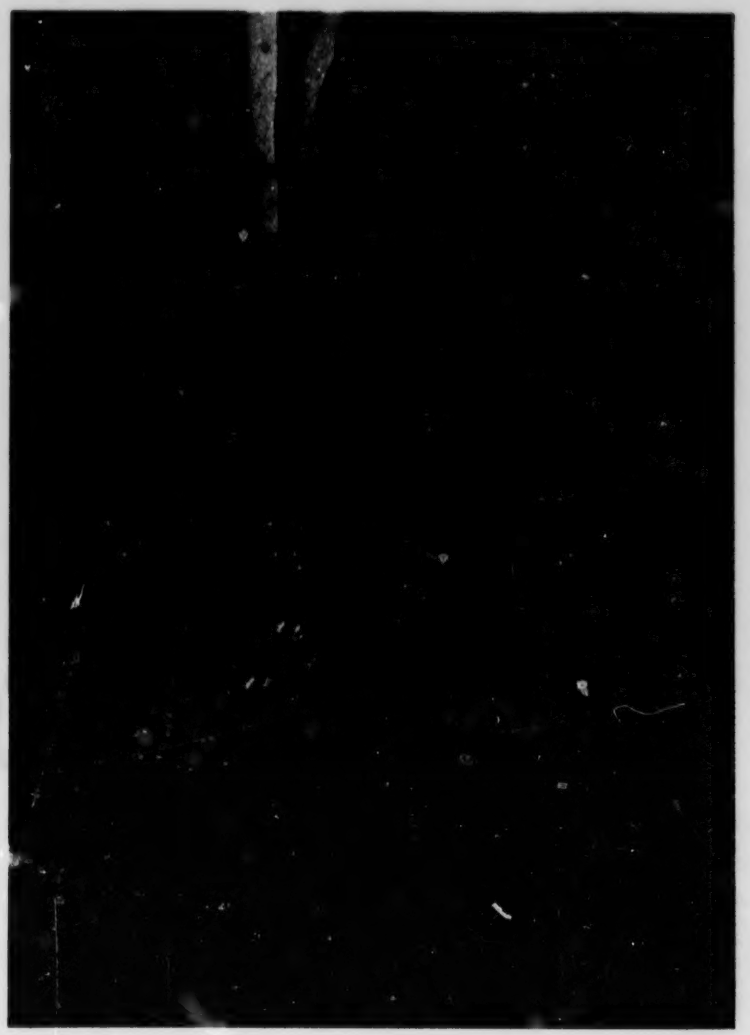


Figure 3-2. Scotia-Liquicoal unbeneficiated coal-water slurry, as received.

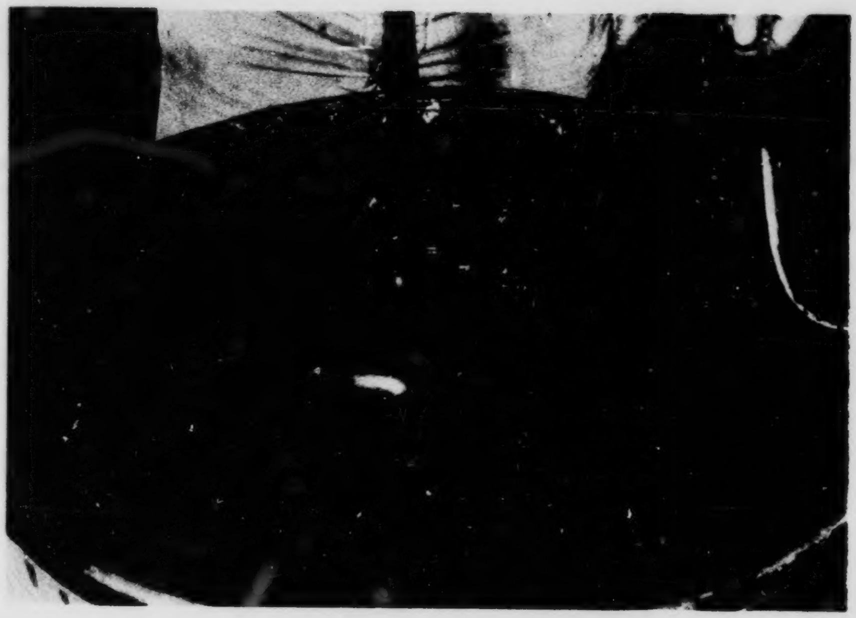


Figure 3-3. Scotia-Liquicoal unbeneficiated coal-water slurry, after one hour of mixing.

Table 3-2

OPERATING CONDITIONS AND TEST RESULTS

Operating Conditions						Results			
Test No.	Bed Temp, (°F)	Gas Velocity (ft/sec)	Ca/S	Bed Height (in)	% O_2	% CE	% SO_2 Capture	NO_x (ppm)	CO (ppm)
62.01	1562	6.7	1.8	25.8	3.0	93.5	48.2	267	203
62.02	1565	8.0	2.4	24.3	3.0	96.2	61.6	275	813
62.03	1557	6.6	2.9	24.8	3.4	96.1	55.2	265	188
62.04	1653	6.3	2.5	23.3	2.9	97.9	26.5	252	104
62.05	1748	6.4	2.8	26.5	3.1	95.8	18.8	301	133
62.06	1559	6.4	2.6	24.3	3.0	96.5	66.1	255	409
62.07	1557	4.6	2.5	25.0	3.0	94.5	57.2	228	126
62.08	1528	3.6	1.7	22.3	3.0	97.4	48.1	236	116
62.09*	1563	6.7	1.2	22.8	3.2	98.2	52.0	234	520
62.10	1561	6.5	1.0	22.8	3.0	96.9	33.9	254	237
63.01	1549	6.7	2.9	27.5	2.8	93.3	86.3	117	1451
63.02	1557	5.5	2.9	26.0	3.1	95.9	87.9	144	335
63.03	1551	8.0	3.0	28.8	2.9	94.0	81.3	155	1710
63.04	1562	6.8	4.9	28.8	3.1	92.9	94.1	136	1404
63.05	1649	6.7	2.9	28.5	3.0	92.2	80.5	157	888
63.06	1731	6.8	3.0	30.0	3.1	97.6	68.3	201	763
63.07	1548	6.6	1.0	24.8	4.1	94.5	48.4	164	450
63.08*	1562	6.9	2.7	28.0	3.2	95.1	86.3	129	1174
63.09	1552	5.2	3.0	27.3	3.2	93.6	79.6	100	301
64.01	1493	7.5	0.0	33.0	2.8	94.3	51.9	112	433

---

* Ash Recycle Test

The thickener underflow was shipped to B&W in the form of a filter cake. This was done to reduce transportation costs and to avoid possible freezing. The filter cake was shipped in 55-gallon drums and appeared as shown in Figure 3-4 when received at B&W. The proximate, ultimate, and ash analysis, along with particle size distribution, of the cake is included in Appendix A. The filter cake was slurried with water to bring the moisture concentration to 70%. This concentration was specified by EMR to be representative of the thickener underflow slurry as it would leave a coal-cleaning plant. Figure 3-5 shows the thickener underflow filter cake after it was slurried to a 70% moisture content. The slurried cake contained some large particles that had to be screened out before pumping through the system. Also, slurry in the feed tank required continuous agitation to prevent settling in the bottom of the tank.

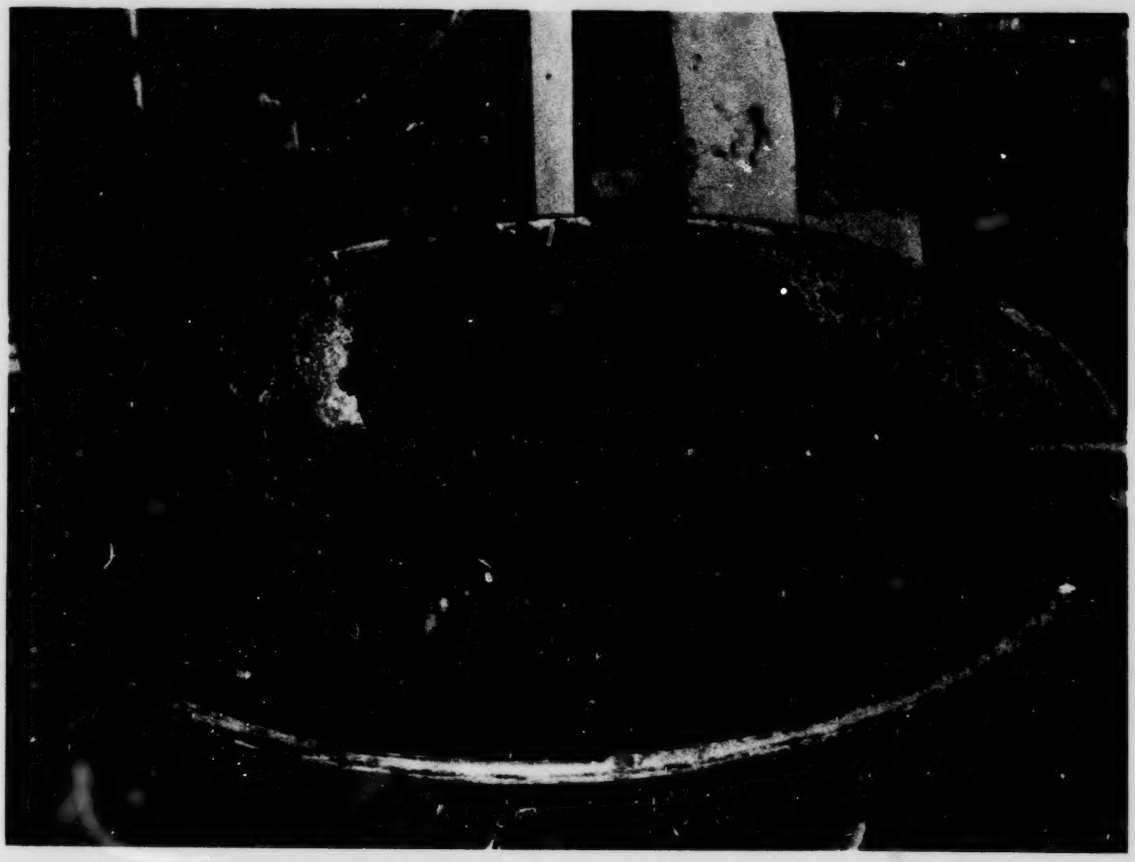


Figure 3-4. Thickener underflow filter cake, as received.

Figure 3-5. Thickener underflow slurry, 30% solids.

COMBUSTION TESTS

A summary of the major operating conditions and test results for the Carbogel beneficiated slurry (Tests 62.01 - 62.10), Scotia-Liquicoal unbeneficiated slurry (Tests 63.01 - 63.09), and the thickener underflow slurry (Test 64.01) is given in Table 3-2. Detailed data (material balance, chemical analysis, and results summary) for each test is contained in Appendix B. The reduced data reported for each test condition is the result of averaging raw data (pressures, temperatures, etc.) over the steady-state time interval and performing calculations on the averaged data. The following information pertains to the reduced data reported in Appendix B.

Material Balance

- Fluidizing air is supplied by the forced-draft fan.
- Transport air pneumatically conveys limestone to the bed.
- Purge air is used to keep in-bed pressure sensing lines clear. This stream is a small percentage of total air input.
- Probe air is introduced through annular area of slurry feed probe. This airstream disperses slurry as it enters the bed and also keeps tip of the probe clear of bed material that could cause plugging.
- Recycle air pneumatically transports ash caught by the cyclone back to the fluidized bed.
- Cyclone hopper overflow is the ash caught by the cyclone that is not recycled to the bed.
- Cyclone outlet dust is the ash removed in the baghouse.
- The flue gas flow rate is calculated based on air and fuel rates, combustion efficiency, sulfation efficiency, and calcination. It is assumed that limestone calcination ($CaCO_3 \rightarrow CO_2 + CaO$) is 100% complete in the bed.

Summary of Results

- Excess air is calculated from the percentage of oxygen in flue gas.
- The calcium-to-sulfur ratio is based on calcium in the limestone and sulfur in the fuel.
- Normalized sulfur capture is what would be obtained if 100% sulfur balance was achieved. Normalized value, based on total sulfur leaving the system, will be used in plots where sulfur capture is a variable.
- The bed temperature is the average of three temperature measurements taken in the bed below the in-bed cooling surface.
- Freeboard temperatures are measured at these distances from the distributor plate:

Position No.	Distance (ft)
1	3.46
2	6.38
3	10.38
4	14.38

- Preheat temperature is that of the fluidizing air in the windbox.
- Plate pressure drop, bed pressure drop, and bed height are calculated from a pressure profile as shown in Figure 3-6.

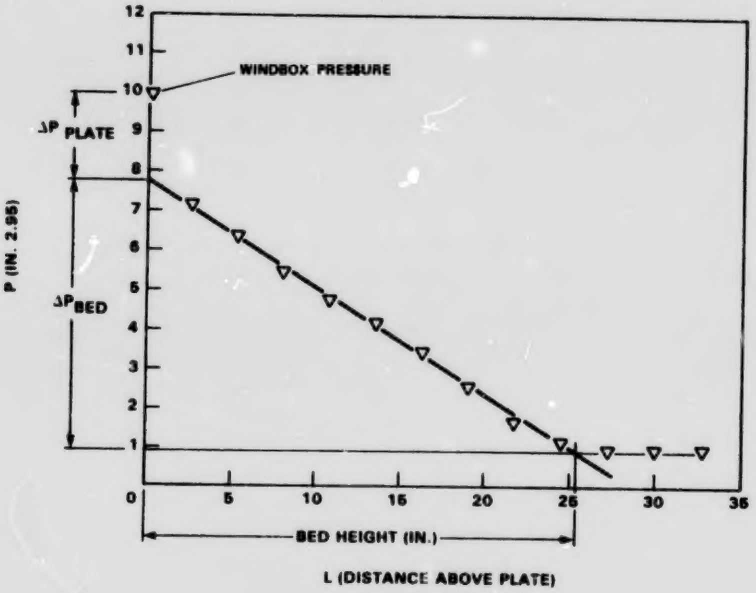


Figure 3-6. Determination of ΔP_{plate}, ΔP_{bed} and bed height.

Carbogel Beneficiated Slurry -- Test Series 62

From an operational standpoint, the beneficiated slurry was the best of the three fuels tested. The slurry flow rate was very stable at all conditions tested, and the excess air (stack O_2) was also very steady (usually within ±0.2 percentage points of the planned 3%).

As a consequence of the low sulfur content of the beneficiated fuel (about 0.5%), the required limestone input rate was also very low (1 - 4 lbs/hr). Since the limestone feeder was designed for higher flow rates (more than 10 lbs/hr), some inaccuracy was introduced when operating in this low range. Errors in the limestone feed measurement became evident when a calcium balance was performed. For the test conditions where the calcium balance was poor, the limestone feed rate was adjusted to maintain a reasonable balance.

Two test conditions in Series 62 (Tests 62.04 and 62.05) yielded unreasonable sulfur balances (179.1% and 369.4% respectively). Stack SO_2 measurement for both tests indicated more sulfur in the flue gas than was being fed to the unit in the fuel. The SO_2 analyzer was calibrated during each test, and in both cases, the analyzer appeared to be reading properly according to calibration. We thought the fuel sulfur content could have increased dramatically for both tests. This was not the case, since sulfur content ranged from 0.49% - 0.54% for the entire series. Carbon, sulfur, and moisture were measured for each test condition (Table 3-3); no significant variation was observed in any of the three measured values. No conclusions were made concerning high SO_2 measurements in Tests 62.04 and 62.05, but a normalized sulfur capture was calculated and is used in the data analysis.

Slurry viscosity was measured at each condition and did not vary appreciably throughout the test series (Table 3-4). The size analyses of the original bed material (Reed limestone), cyclone, and bed drain ash are shown in Tables 3-5 and 3-6. Combustion efficiencies for Series 62 were in the range of 93.5% - 98.2%. The highest combustion efficiency was obtained in the ash recycle test; the range of sulfur capture efficiency attained was 18.8% - 66.1% for a range of calcium-to-sulfur ratios of 1.0 to 2.9.

Scotia-Liquicoal Unbeneficiated Slurry -- Test Series 63

Compared with the Carbogel fuel testing, stack O_2 (excess air) fluctuations were greater for the unbeneficiated slurry test, making the pilot unit more difficult to control. Although the slurry was premixed before loading into the feed tank, it was not as well mixed as the Carbogel slurry and, therefore, was most likely less homogeneous as it entered the bed. We feel that this might have been one reason for such large swings in excess air.

Throughout this test series, the coal-water-slurry feed rate cycled 5 - 7 lbs/hr from the planned rate. The cycling, also present in the previous series, was caused by cycling of the positive-displacement feed pump. The fluctuations in excess air noted previously were not in phase with fluctuations in slurry rate.

Note that the unbeneficiated slurry contained more moisture, sulfur, ash and had a lower gross heating value than the beneficiated slurry (Table 3-1). Table 3-3 again indicates little variation in carbon, sulfur, and moisture content throughout the series. The unbeneficiated slurry viscosity (Table 3-4) varied more from test to test (688 - 1187 cP) than did the beneficiated slurry viscosity. As in Series 62, Reed limestone was used as bed material.

Table 3-3

CARBON, SULFUR, AND MOISTURE CONTENT MEASURED AT RECIRCULATION LINE OUTLET

Test No.	Carbon	Sulfur	Total Moisture
62.01	61.1	0.54	28.1
62.02	61.1	0.55	28.2
62.03	64.9	0.53	28.5
62.04	60.9	0.53	28.4
62.05	60.9	0.56	28.4
62.06	60.8	0.55	28.3
62.07	60.8	0.54	28.3
62.08	60.4	0.51	28.2
62.09	61.0	0.51	28.2
62.10	61.0	0.49	29.0
63.01	40.1	3.42	41.0
63.02	39.5	3.53	41.1
63.03	39.9	3.37	40.3
63.04	39.6	3.38	40.1
63.05	40.7	3.39	38.9
63.06	39.8	3.30	40.2
63.07	40.0	3.47	39.5
63.08	39.6	3.69	39.5
63.09	39.8	3.40	39.3
64.01 (1)*	11.5	0.06	68.6
(2)	11.0	0.06	69.7
(3)	11.5	0.09	69.7
(4)	11.1	0.06	69.6
(5)	10.8	0.06	70.0

---

* Samples taken at one-hour intervals

Table 3-4

VISCOSITY (cP) MEASURED AT APPROXIMATELY 100 SEC^{-1} SHEAR RATE

Carbogel Beneficiated Slurry		Scotia-Liquicoal Unbeneficiated Slurry		Thickener Underflow		
Test No.	μ(cP)	Test No.	μ(cP)	Test No.	Time	μ(cP)
62.01	1467	63.01	1072	64.01	1100	32
62.02	1380	63.02	767	64.01	1200	30
62.03	1398	63.03	1187	64.01	1300	24
62.04	1348	63.04	688	64.01	1400	20
62.05	1403	63.05	1076	64.01	1500	19
62.06	1317	63.06	858			
62.07	1403	63.07	771			
62.08	1362	63.08	728			
62.09	1422	63.09	701			
62.10	1399					

Table 3-5

SIZE ANALYSIS OF LIMESTONE AND SAND BED MATERIAL (% through)

Mesh	Micron	Series 62 Reed Limestone	Series 63 Reed Limestone	Series 64 Sand
1/4"	6350	100.0	100.0	100.0
4M	4750	97.7	99.2	100.0
8M	2380	85.1	95.1	100.0
16M	1190	61.0	57.0	44.7
30M	595	42.6	36.4	3.1
50M	297	28.1	23.7	0.1
100M	149	17.8	15.6	0.
200M	74	10.9	10.2	0.
325M	44	6.7	7.1	0.
Mass Mean Diameter*		1271	1139	1365

---

* Micrometers

Table 3-6

SIZE ANALYSIS OF ASH STREAMS
(% through)

		Carbogel Beneficiated Coal-Water Slurry -- Series 62									
Bed Ash		Test No.									
Mesh	Micron	62.01	62.02	62.03	62.04	62.05	62.06	62.07	62.08	62.09	62.10
1/4"	6350	99.2	100.	99.4	100.	99.4	100.	100.	99.6	100.	100.
4M	4750	96.7	98.6	98.0	99.2	98.8	99.6	99.3	99.1	99.0	99.3
8M	2380	73.7	81.7	88.7	86.2	94.6	94.1	88.7	90.5	83.9	87.6
16M	1190	35.4	48.3	59.8	49.9	76.0	65.5	53.9	62.5	35.4	49.1
30M	595	7.2	13.4	20.0	11.9	33.5	21.7	14.4	21.6	5.4	10.2
50M	297	0.2	0.1	0.5	0.2	1.5	0.4	0.2	0.8	0.2	0.2
100M	149	0.13	0.07	0.12	0.11	0.2	0.07	0.10	0.22	0.13	0.1
200M	74	0.09	0.05	0.09	0.09	0.12	0.05	0.06	0.20	0.11	0.08
325M	44	0.05	0.04	0.07	0.07	0.11	0.04	0.03	0.18	0.09	0.06
Mass Mean Diameter*		1989	1647	1416	1547	1088	1215	1454	1325	1751	1535
Cyclone Ash											
16M	1190	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.
30M	595	99.9	99.9	99.9	99.9	99.8	99.9	99.9	99.9	99.9	100.
50M	297	98.8	92.0	97.6	99.0	98.2	98.6	98.5	99.3	99.8	99.9
100M	149	93.2	68.8	85.6	85.4	89.6	77.7	84.2	85.4	98.4	98.3
200M	74	79.9	49.6	69.9	67.7	76.2	58.4	59.7	63.8	89.0	90.6
325M	44	61.3	31.0	50.2	50.2	60.4	38.5	37.5	42.4	69.6	76.4
Mass Mean Diameter*		58	127	78	76	66	95	88	81	42	38

		Scotia Liquicoal Unbeneficiated Coal-Water Slurry - Series 63									Series 64 Thickener Underflow
Bed Ash		Test No.									
Mesh	Micron	63.01	63.02	63.03	63.04	63.05	63.06	63.07	63.08	63.09	64.01
1/4"	6350	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.
4M	4750	98.6	99.0	99.2	99.7	99.7	99.5	99.3	99.3	99.7	99.7
8M	2380	84.6	93.8	94.4	95.4	92.5	94.0	96.0	96.0	95.7	88.3
16M	1190	50.5	65.8	51.2	57.6	61.2	65.9	67.5	67.5	61.2	29.0
30M	595	16.9	26.7	16.0	19.2	22.6	27.6	30.8	30.8	24.7	0.80
50M	297	0.3	1.2	0.1	0.3	0.7	1.0	1.2	1.2	1.3	0.23
100M	149	0.2	0.1	0.	0.	0.1	0.2	0.	0.	0.1	0.19
200M	74	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.15
325M	44	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.10
Mass Mean Diameter*		1560	1206	1372	1272	1276	1188	1189	1127	1208	1736
Cyclone Ash											
16M	1190	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.
30M	595	99.9	99.9	99.8	100.	99.9	99.9	99.8	99.9	99.9	99.6
50M	297	97.4	99.4	83.3	99.96	96.2	92.9	88.8	99.5	99.5	95.5
100M	149	93.8	79.2	58.1	99.7	84.7	54.4	67.1	93.9	83.6	85.2
200M	74	87.9	57.1	45.4	97.8	66.5	36.0	53.1	80.3	57.8	67.2
325M	44	79.0	44.5	36.0	92.4	45.7	24.3	40.5	63.7	36.5	40.5
Mass Mean Diameter*		49	90	159	29	86	151	131	54	87	90

---

*Micrometers

The sulfur content of this fuel (3.30% - 3.69%) allowed limestone rates that were in the more accurate range of the feeder (20 - 50 lbs/hr). Higher limestone rates and more fuel ash input resulted in larger amounts of bed drain, cyclone, and baghouse ash. Better resolution was obtained when weighing the output streams. This produced more accurate measurements of flow rates and material balances. The material balances for this series are reported in Appendix B. Also in Appendix B, the Freeboard No. 1 temperature is shown as zero degrees for Tests 63.08 and 63.09 because of a malfunctioning thermocouple. This temperature measurement is not used in the performance calculations.

The range of combustion efficiencies for Series 63 was 92.2% - 97.6%, which is similar to the range obtained in Series 62. The highest combustion efficiency was reached with a 1731°F bed temperature with no recycle, but sulfur capture was low (68.3%) for that temperature. Sulfur capture ranged from 48.4% - 94.1% for a range of calcium-to-sulfur ratios of 1.0 - 4.9. The range of sulfur capture was generally much higher than that of Series 62. This can be attributed to a higher in-bed concentration of SO_2 (which is the driving force for SO_2 absorption) resulting from a higher sulfur content in the fuel.

Thickener Underflow -- Test Series 64

The operational approach taken for testing thickener underflow was to start the test unit on coal and then make a gradual transition in feed from coal to thickener underflow. During the initial attempt at a baseline test condition, numerous problems with plugged slurry lines leading to the feed probe were encountered. We believe the plugging was caused by large particles in the as-received thickener underflow cake. To solve this problem, the slurry feed tank was drained and cleaned, and the slurry was screened before reloading into the tank. A second attempt made at baseline conditions (6 ft/sec velocity, 1562°F bed temperature, and 3% stack O_2) resulted in severe agglomeration of the bed material (Figures 3-7 and 3-8) as coal feed was decreased and thickener underflow feed was increased. This occurred with a 400° - 500°F air preheat temperature after approximately 15 minutes of operation. The agglomerates formed were relatively soft and easily broken up.

Figure 3-7. Agglomerate formed during thickener underflow test, looking into furnace.

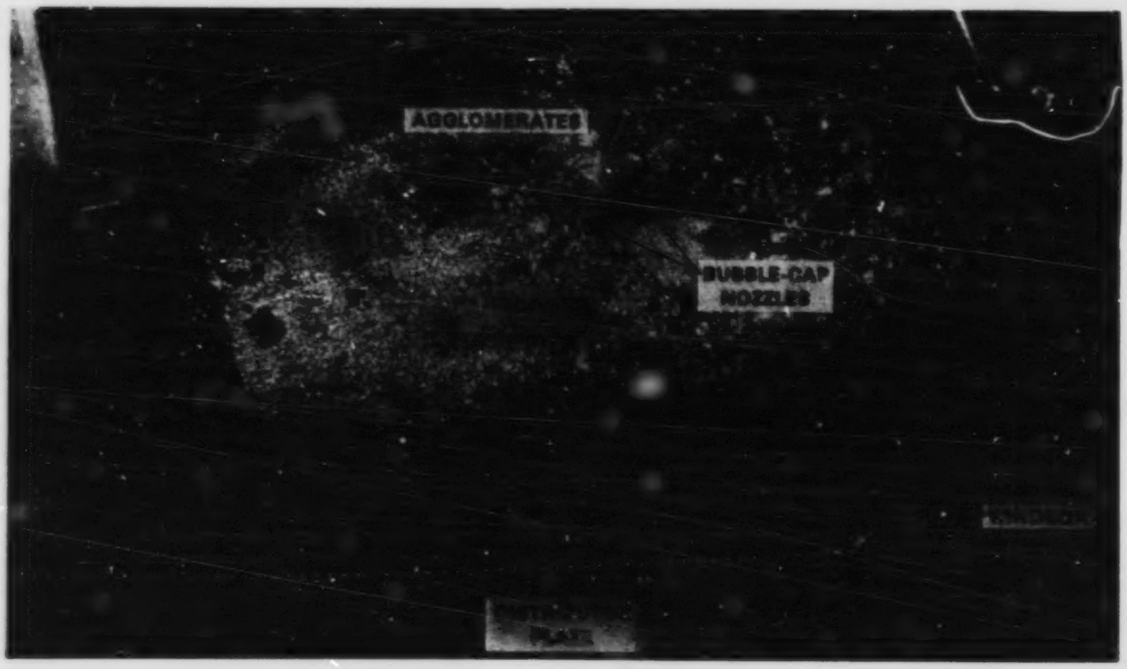


Figure 3-8 Agglomerate formed during thickener underflow test on distributor plate.

In an attempt to eliminate bed agglomeration, we decided to operate at higher gas velocity (8 ft/sec) and higher air preheat temperature (800° - 1000°F). Also, during the two previous attempts, the slurry-injection point was positioned 2-3/4 inches into the bed from the furnace side wall. Since the transport air entering the center of the bed with the coal feed is at approximately 80°F, a cold region develops at that point in the bed. We thought that the slurry feed (not preheated) and air introduced through the feed probe with the slurry was entering the bed at a point too close to the coal feed point. For the next attempt, the slurry feed point was positioned one-half inch into the bed from the furnace side wall, therefore, also farther away from the coal feed point.

In the third attempt, the same startup procedure was followed, with the thickener underflow rate being increased by 10-lb/hr increments over a 75-minute period. A steady condition was reached: slurry feed rate approximately 215 - 220 lb/hr, coal rate approximately 10 lbs/hr, 8 ft/sec velocity, approximately 1450°F bed temp. After running at that condition for approximately one hour, the coal feed was terminated and fuel feed was switched to 100% thickener underflow. As this was done, bed temperature dropped to approximately 1050°F in 15 minutes following the termination of coal flow. An attempt to re-establish coal feed was unsuccessful because an agglomerate had formed over the coal feed nozzle.

A final run was successfully accomplished with a 200-lb/hr thickener underflow/14 lb/hr coal split. The unit was run at this condition for approximately four hours and ash samples (cyclone, baghouse, and bed drain) were collected. During the four-hour test period, the feed probe plugged at the tip three times. This was probably due to small agglomerates forming at the slurry-injection point. Stack O_2 levels varied from 2% - 3% during the test. Concentrations of NO_x and SO_2 were fairly constant throughout the test.

Since there was virtually no sulfur (0.07%) in the thickener underflow feedstock, sand, rather than limestone was used as bed material. The sand was double-screened and the size analysis is shown in Table 3-5. The coal fed to the unit with the thickener underflow was Pittsburgh No. 8; its analysis is given on the data output sheet in Appendix B. Approximately 33% of the total heat input was supplied by the coal. The combustion efficiency (94.3%) and sulfur capture (51.9%) are also included in Appendix B and are based on coal and thickener underflow feed. Since no limestone sorbent was used, sulfur capture was achieved by inherent calcium in the fuel ash. The bed drain and cyclone ash size analyses are shown in Table 3-6.

HEAT TRANSFER COEFFICIENTS

Heat transfer coefficients were computed for each of the instrumented, subcooled, in-bed tubes. The coefficients are tabulated in Table 3-7. The average in-bed coefficient ranged from 40 - 57 Btu/hr-ft^2-°F, which is typical for fluidized-bed combustors operating with a limestone bed. Note that for Test 64.01 (thickener underflow), no in-bed cooling was used. A more detailed heat transfer analysis on each instrumented tube is given in Appendix C.

Table 3-7

HEAT TRANSFER COEFFICIENT FOR IN-BED TUBES

(Btu/hr-ft^2-°F)

Test No.	Tube No. 1 13 in From Plate	Tube No. 2 18 in From Plate	Tube No. 3 23 in From Plate	Ave (1+2+3)/3
62.01	39.12	52.30	42.88	44.77
62.02	35.36	44.85	42.49	40.90
62.03	42.97	52.99	42.97	46.31
62.04	46.20	57.86	48.13	50.73
62.05	49.27	62.19	51.13	54.20
62.06	39.23	51.73	43.39	44.79
62.07	52.27	66.00	52.27	56.85
62.08	46.73	60.88	51.44	53.02
62.09	43.39	55.34	45.37	48.03
62.10	41.04	54.21	42.91	46.05
63.01	47.76	58.45	53.10	53.11
63.02	46.32	56.93	48.43	50.56
63.03	40.79	49.92	45.35	45.35
63.04	47.64	60.19	51.82	53.22
63.05	42.12	29.43	48.47	40.01
63.06	43.36	56.47	47.72	49.18
63.07	42.60	53.92	47.12	47.88
63.08	40.64	51.44	47.12	46.40
63.09	42.78	51.40	44.92	46.37
64.01		No In-Bed Cooling		

Section 4

DISCUSSION

The purpose of this section is to examine by two-dimensional trend analysis the effect of various operating conditions on FBC performance. The major operating conditions that were varied during the test program were bed temperature, superficial gas velocity, and calcium-to-sulfur ratio. The effect of these conditions on combustion efficiency, sulfur capture, and NO_x emissions is investigated. Also, recycle of cyclone fly ash was tested to determine its potential for increasing combustion efficiency.

CARBOGEL BENEFICIATED COAL-WATER SLURRY -- TEST SERIES 62

Combustion

In fluidized-bed coal combustion, combustion efficiency generally decreases with increasing superficial gas velocity due to increased carbon loss to elutriation. The same trend was observed for the Carbogel beneficiated slurry (Figure 4-1) for a restricted range of bed temperature. For Tests 62.01 and 62.07, combustion efficiency was low.

In trying to rationalize why Tests 62.01 and 62.07 had lower efficiencies, we looked at the amount of carbon leaving the system as a percentage of total carbon feed. For Tests 62.01 and 62.07, the values were 8.1 and 6.9, respectively. The other tests plotted on Figure 4-1 had values in the range of 3.6 to 4.6. We are not certain why the carbon loss was higher for Tests 62.01 and 62.07, but this may have been due to particle size changes caused by agglomeration of slurry droplets in the bed. Investigation of agglomeration properties was not a part of this research effort, but it has been reported by other investigators [1] that agglomeration is important to slurry combustion in a fluidized bed.

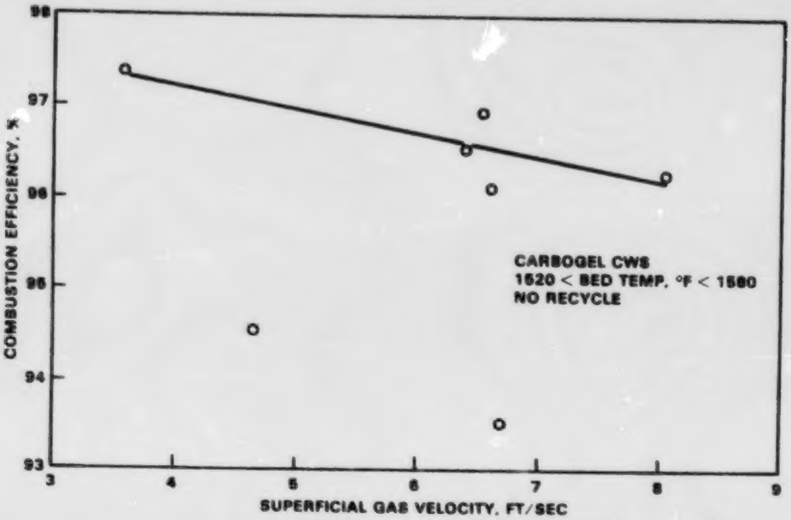


Figure 4-1. Effect of superficial gas velocity on combustion efficiency for Carbogel CWS.

Figure 4-2 shows that carbon monoxide (CO) emissions were also a function of the superficial gas velocity. CO formed by incomplete combustion of carbon in the fuel increases with increasing gas velocity due to decreased carbon residence time in the system. Also, Cen, et al. [1] have reported that the high water content of coal-water slurry may produce a high concentration of water vapor in the bed. This causes the following gasification reactions to intensify:

$$C + H_2O \longrightarrow CO + H_2$$

$$1/2C + H_2O \longrightarrow 1/2CO_2 + H_2$$

The oxygen-rich zone in a fluidized bed is a thin layer just above the distributor plate. Fuel has little chance of mixing well with the oxygen in this region; therefore, the burning process actively moves toward the upper region of the bed, which is somewhat oxygen lean and water-vapor rich. As superficial velocity increases, a higher percentage of the total combustion takes place in the uppermost region of the bed and in the freeboard; this would enhance the gasification reactions.

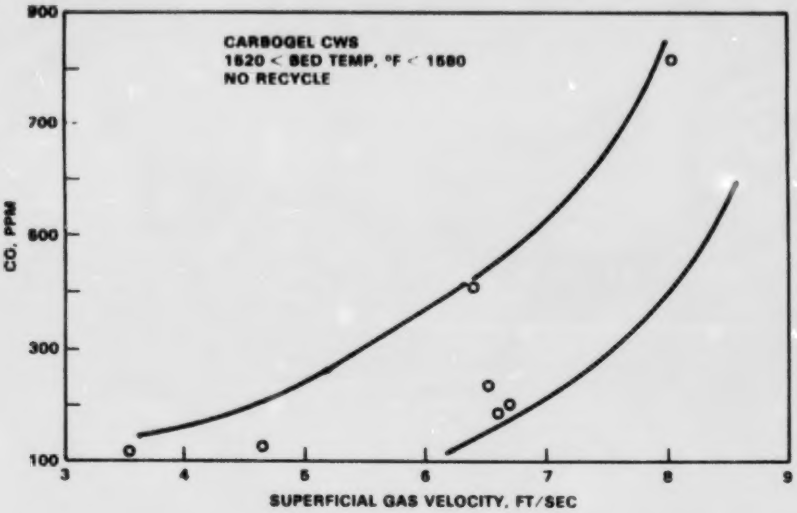


Figure 4-2. Effect of superficial gas velocity on CO emissions for Carbogel CWS.

Evaluating the cyclone efficiency indicates a trend relating efficiency to char recovery. Figure 4-3 shows that as the cyclone efficiency increases, the percentage of unburned carbon lost to the cyclone outlet decreases. This trend can be expected, since unburned char particles in the carry-over are smaller in size and have a lower density compared with solid particles of lime and sulfated lime. Therefore, recovery of the char particles is less efficient and results in a lower overall cyclone efficiency [2].

NO_x Emissions

Emissions of NO_x in fluidized-bed combustors contain mainly nitric oxide (NO) and nitrogen dioxide (NO_2); NO is the dominant species. The mechanisms describing the formation and destruction of NO_x in an FBC are complicated, but the principle NO_x-forming reactions are the fixation of atmospheric nitrogen ("thermal" NO) and the oxidation of fuel-bound nitrogen. Fixation is not significant in fluidized-bed combustion because of relatively low operating temperatures.

Oxidation of fuel-bound nitrogen begins with the evolution of volatile nitrogen compounds during thermal decomposition of coal particles [3]. The rate of evolution of nitrogen compounds is proportional to the rate of coal devolatilization, which is dependent on coal volatile content, particle size, and bed temperature. Figure 4-4 shows the relationship between NO_x emissions and bed temperature for Carbogel slurry.

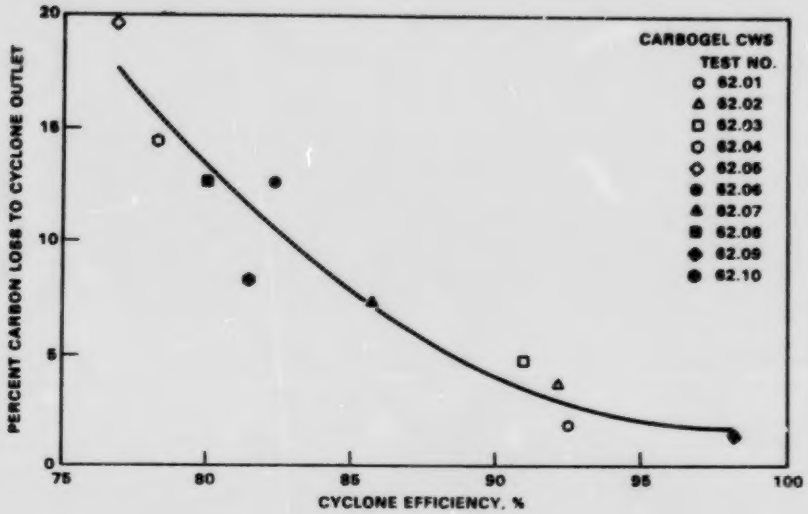


Figure 4-3. Percentage of carbon loss to cyclone outlet as a function of cyclone efficiency for Carbogel CWS.

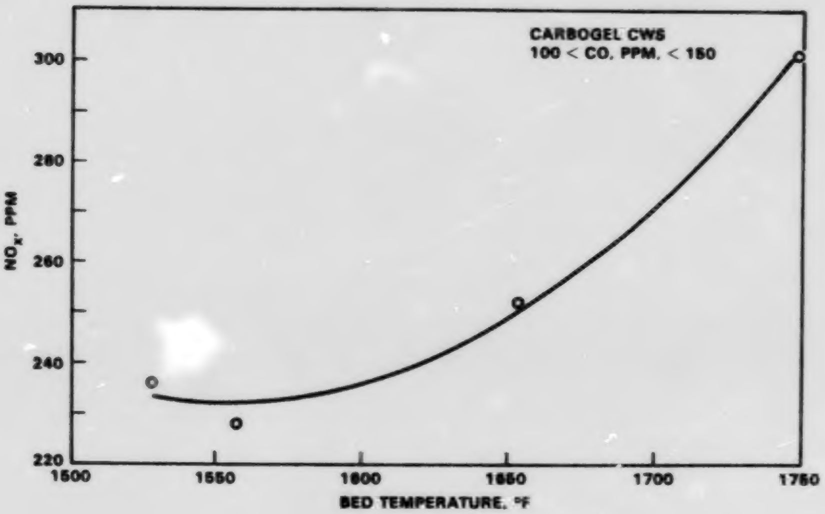


Figure 4-4. NO_x emissions as a function of bed temperature for Carbogel CWS.

Figure 4-5 indicates that NO_x levels were also a function of CO concentration. This stems from the fact that NO_x formation is suppressed when reducing conditions exist in the bed. There is also evidence that a heterogeneous NO-reducing reaction occurs between NO and solid carbon in the presence of CO. This is further considered in the discussion of the test results for the Scotia-Liquicoal unbeneficiated slurry.

Sulfur Capture

The operating parameters having the greatest effect on sulfur capture were the calcium-to-sulfur ratio and bed temperature. The increase in SO_2 capture with increasing Ca/S ratio for a given range of bed temperature is shown in Figure 4-6. The effect of bed temperature on SO_2 capture for a narrow range of Ca/S ratio is given in Figure 4-7. Note that sulfur capture decreases as bed temperature increases from 1550°F to 1650°F. From our previous experience with coal, we can expect sulfur capture to decrease as the bed temperature varies from 1550°F, which has proven to be in the range of optimum temperature for most limestone.

SCOTIA-LIQUICOAL UNBENEFICIATED COAL-WATER SLURRY -- TEST SERIES 63

Combustion

It is advantageous to minimize emission levels of CO in the flue gas because of the operational danger, gas toxicity, and thermal penalty involved. Series 63 showed a good correlation between CO emissions and bed temperature (Figure 4-8). CO is shown to decrease significantly as bed temperature is increased from about 1550° to 1750°F. This is due to an increased combustion intensity at higher temperatures, which results in more efficient conversion of carbon and CO to CO_2. As with the beneficiated Carbogel slurry (Figure 4-2), CO levels increased with increasing superficial gas velocity (Figure 4-9). Data from Test 63.07 falls below the curve because of higher excess air (23% compared with 15% - 17% for the other points).

Figure 4-10 shows the effect of bed temperature on combustion efficiency for a narrow range of superficial gas velocity. An increase in efficiency with temperature is expected, but note that for Test 63.05, the combustion efficiency was 92.2% when we might have expected something in the 95% - 96% range. This is examined in more detail in Table 4-1.

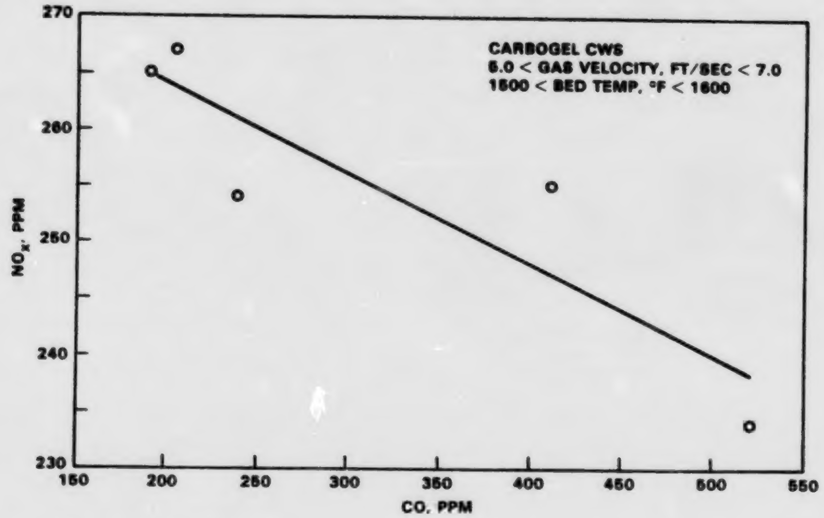


Figure 4-5. NO_x emissions versus CO emissions for Carbogel CWS.

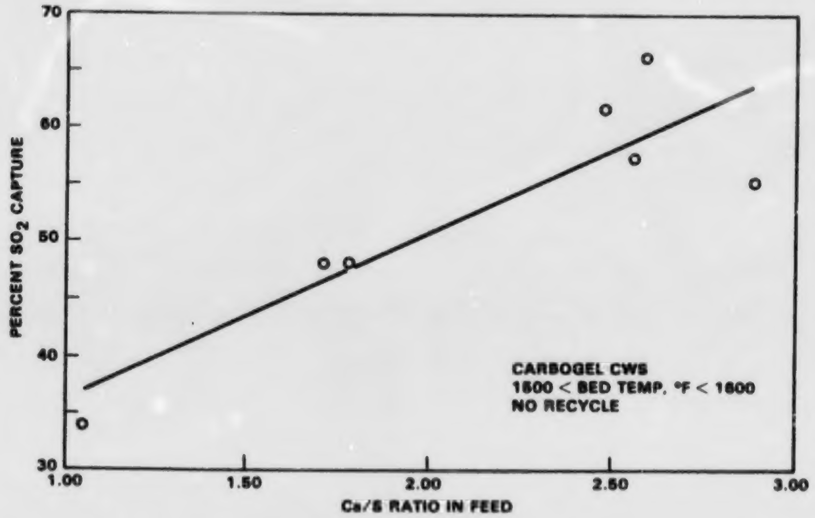


Figure 4-6. Effect of Ca/S ratio on sulfur capture for Carbogel CWS.

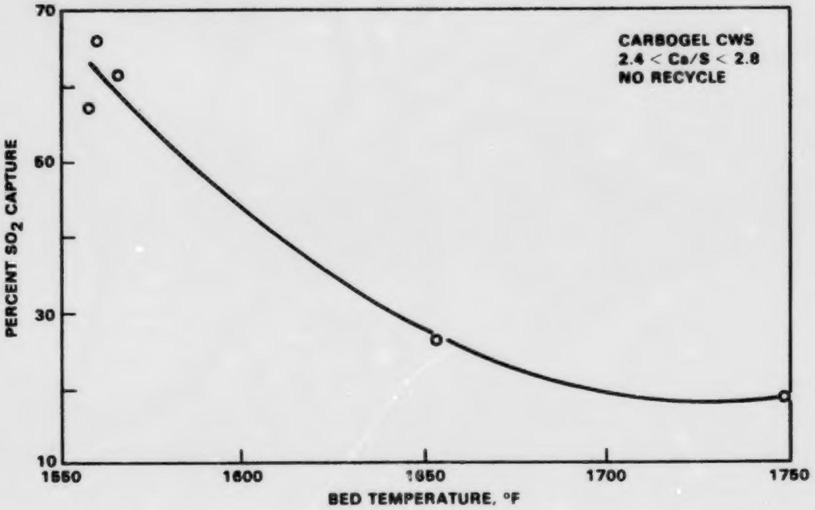


Figure 4-7. Effect of bed temperature on sulfur capture for Carbogel CWS.

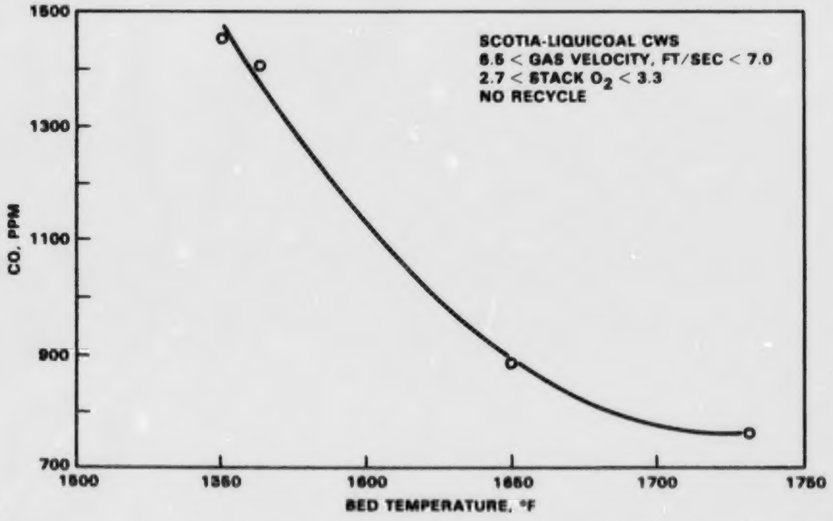


Figure 4-8. CO versus bed temperature for Scotia-Liquicoal CWS.

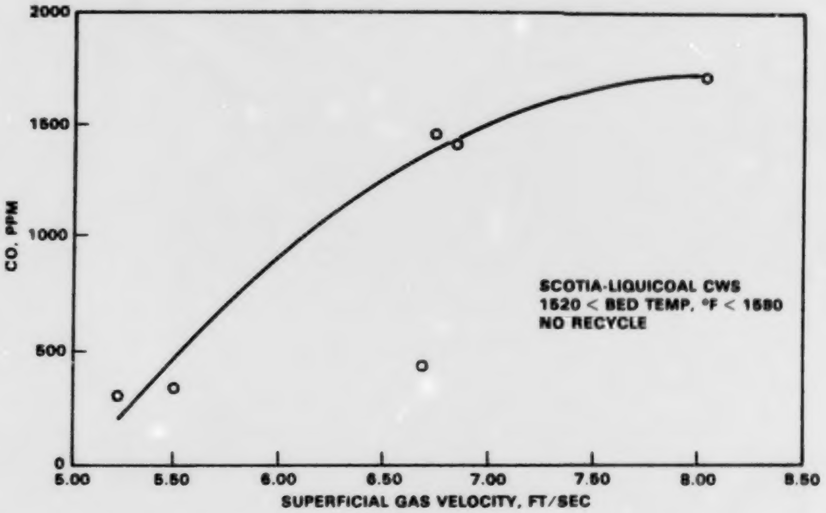


Figure 4-9. CO as a function of superficial gas velocity for Scotia-Liquicoal CWS.

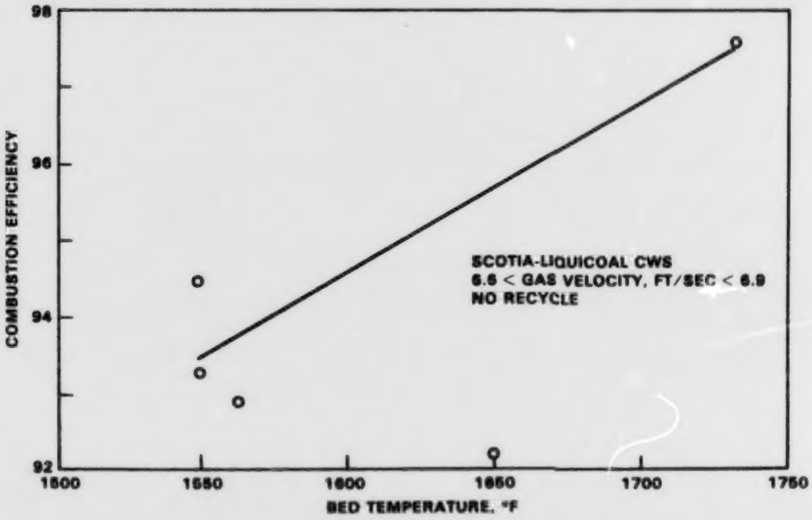


Figure 4-10. Effect of bed temperature on combustion efficiency for Scotia-Liquicoal CWS.

Table 4-1

DATA COMPARISON FOR TEST SERIES 63 -- TEMPERATURE VARIATION

	Test No. 63.04	Test No. 63.05	Test No. 63.06
Bed temp (°F)	1562	1649	1731
Gas velocity (ft/sec)	6.8	6.7	6.8
Bed height (in)	28.8	28.5	30.0
O_2%	3.1	3.0	3.1
CO (ppm)	1404	888	763
Combustion efficiency (%)	92.9	92.2	97.6
Percent carbon in carry-over per total carbon feed	8.7	9.2	2.9
Percent carbon in cyclone outlet (from chemical analysis)	7.2	8.2	8.3
Percent carbon in cyclone catch (from chemical analysis)	14.8	19.8	5.2

The operating parameters for the three tests were similar, except for bed temperature. Note that for Test 63.05, the percentage of carbon in the material caught by the cyclone was high (19.8%) compared with the other tests. This value is based on the chemical analysis and is independent of the measurement of flow rate. We felt that a bad sample or an error in analysis could have caused the carbon measurement to be high, so we analyzed another sample of cyclone-catch material taken within one hour of the first sample. This analysis revealed a carbon content of 19.6%, which was sufficiently close to the 19.8% measured initially to conclude that the analysis was not in error. Therefore, the low combustion efficiency in Test 63.05 was a result of greater carbon loss to carry-over (9.2% carbon in carry-over per total carbon feed).

Experience with fluidized-bed coal combustion shows that combustion efficiency is strongly influenced by coal particle size. Particle size distribution of the coal-water slurry was not measured at each test condition, but we believe that the size distribution did not vary significantly among tests. The carbon, sulfur, and moisture content of the unbeneficiated slurry was constant throughout the test series (refer to Section 3). We feel it is unlikely that size changed enough during a single test to effect such a change in combustion efficiency.

One area in which we do not have a thorough understanding is that of agglomeration of slurry droplets in the bed. This could be a function of slurry type, particle size, method of feeding, or bed temperature. One could speculate that droplet agglomeration had a detrimental effect on combustion efficiency at the 1650°F bed temperature.

The effect of superficial gas velocity on combustion efficiency for a narrow range in bed temperature is shown in Figure 4-11. The data are widely scattered, but the points fall within a bounded region that seems to indicate that combustion efficiency decreases with increasing superficial gas velocity.

NO_x Emissions

The relationship between NO_x level and bed temperature (Figure 4-12) is similar to that shown for the beneficiated coal-water slurry (Figure 4-4). Since NO_x increases and CO decreases (Figure 4-8) with increasing bed temperature, it follows that NO_x emissions are inversely proportional to CO emissions. This is shown in Figure 4-13.

The percentage of carbon in the carry-over solids was found to have a favorable effect on NO_x reduction (Figure 4-14). Figure 4-14 shows evidence that the previously mentioned heterogeneous reactions between NO and char in the presence of CO does occur in fluidized-bed combustors. These reactions, as proposed by Chan [4] are as follows:

$$2NO + C\ (\text{char}) \longrightarrow N_2 + CO_2$$

$$C + NO \longrightarrow CO + 1/2\ N_2$$

Chan noted that the rate of the NO-char reaction was enhanced by the presence of CO. This may be due to a reaction of CO with a chemisorbed oxide film on the char particle surface, making surface sites available for the activated adsorption of NO [4].

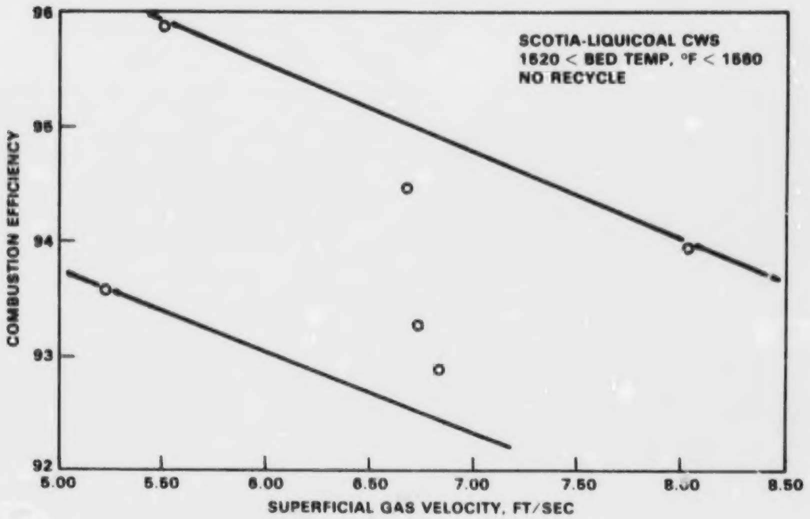


Figure 4-11. Effect of superficial gas velocity on combustion efficiency for Scotia-Liquicoal CWS.

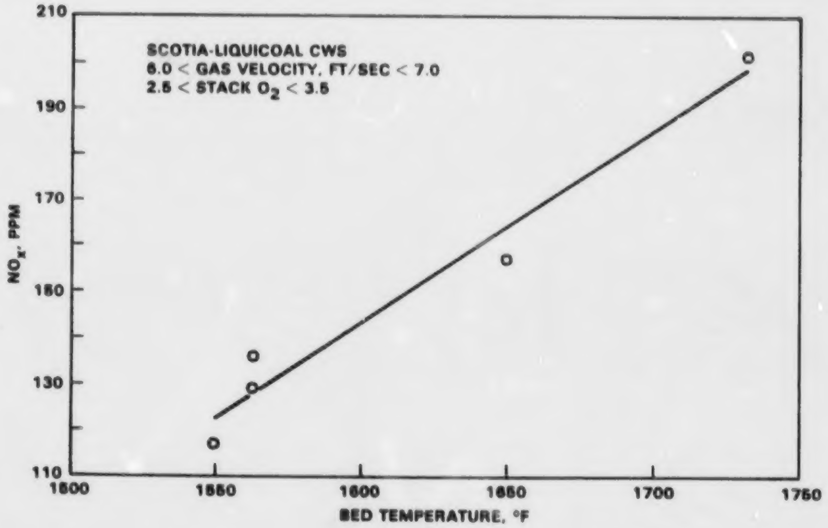


Figure 4-12. NO_x emissions versus bed temperature for Scotia-Liquicoal CWS.

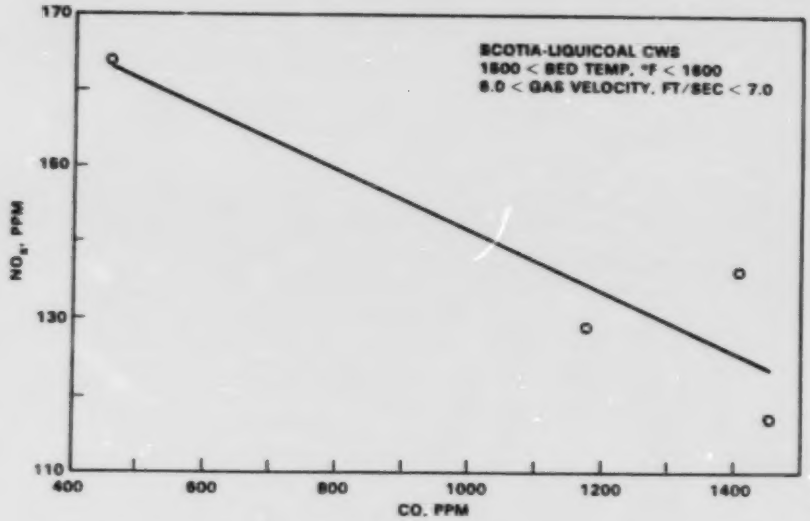


Figure 4-13. NO_x versus CO for Scotia-Liquicoal CWS.

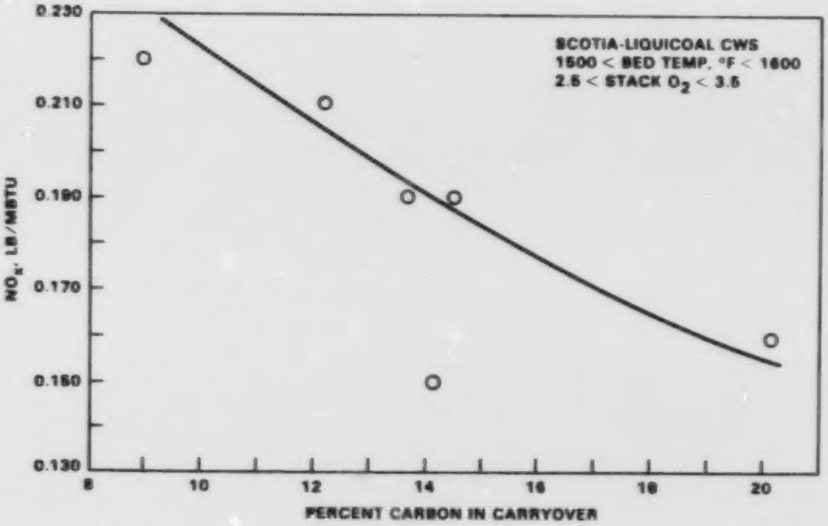


Figure 4-14. Effect of percentage of carbon in carry-over on NO_x emissions for Scotia-Liquicoal CWS.

Sulfur Capture

As with the beneficiated Carbogel slurry, sulfur capture was found to be a strong function of both the Ca/S ratio and bed temperature. Figure 4-15 depicts the effect of Ca/S ratio, and Figure 4-16 shows the dependence of SO_2 capture on bed temperature. Note that sulfur capture does not fall off as rapidly with increasing temperature for this test series as it did for the Carbogel slurry.

Also, the percentage of lime utilization in the spent bed material was related to the solid retention time in the bed. The lime utilization increased from 35% to 41% as the solid retention time increased from 5 to 40 hours (Figure 4-17). Test 63.04 was run at a high Ca/S ratio (5) and Test 63.06 at a high bed temperature (1731°F). This shows that the spent-bed lime utilization was also influenced by Ca/S ratio and bed temperature, as well as the in-bed, solid-retention time.

Effect of Recycle

In general, recycle of cyclone fly ash resulted in an improvement in combustion efficiency. The recycle tests (Tests 62.09 and 63.08) are compared with nonrecycle tests run under similar conditions in Table 4-2. Combustion efficiency was generally 2% - 3% higher with recycle than without.

Above-Bed Combustion

An important point in designing fluidized-bed combustors is the split between in- and above-bed combustion. This is essential in designing in-bed and convective-pass heat transfer surfaces and is directly related to freeboard height. A simplified analysis of freeboard combustion was done based on temperature profiles.

Temperature rise above the bed surface is due to heat release from combustion occurring in that region. Temperature rise is defined as the difference between bed temperature and the highest temperature in the freeboard region. By referencing the temperature rise to the bed temperature, a qualitative comparison of above-bed combustion can be made. Table 4-3 is a tabulation of the temperature rise in the freeboard expressed as a percentage of bed temperature. In most cases, the amount of above-bed combustion was greater for the Carbogel beneficiated slurry (Series 62) than the Scotia-Liquicoal unbeneficiated slurry (Series 63).

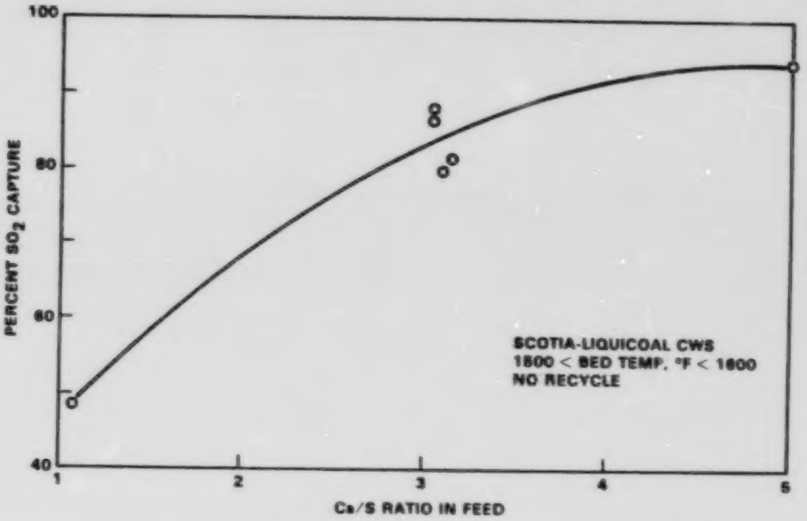


Figure 4-15. Effect of Ca/S ratio on sulfur capture for Scotia-Liquicoal CWS.

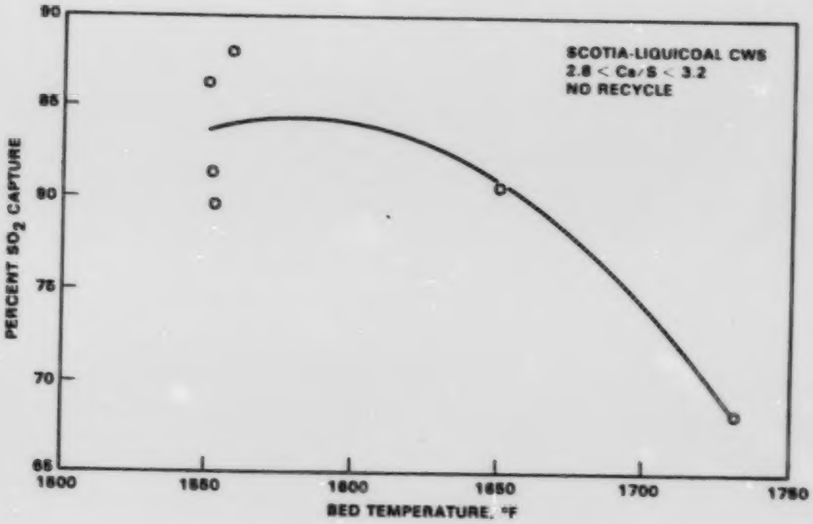


Figure 4-16. Effect of bed temperature on sulfur capture for Scotia-Liquicoal CWS.

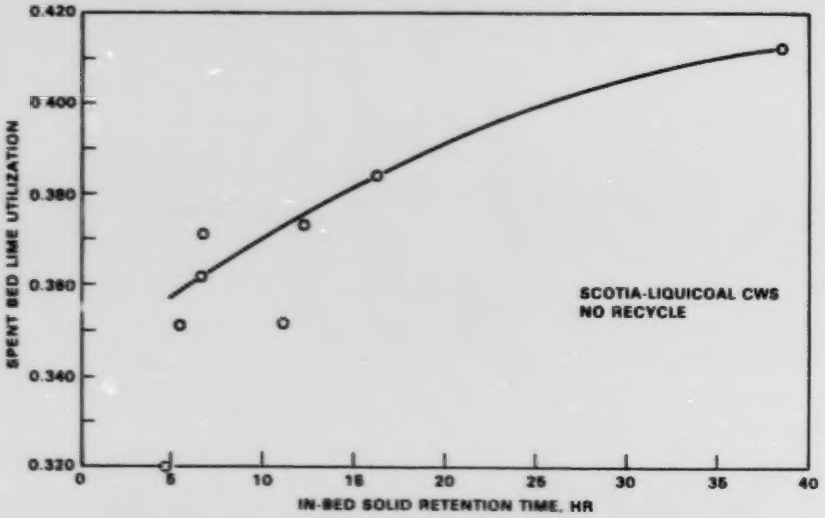


Figure 4-17. Spent-bed lime utilization as a function of in-bed solid-retention time for Scotia-Liquicoal CWS.

Table 4-2

IMPROVEMENT IN COMBUSTION EFFICIENCY AS A RESULT OF RECYCLE

Test No.	Bed Temp. (°F)	Gas Velocity (ft/sec)	Bed Height (in)	% O_2	Recycle/Fuel Ratio	% CE
*62.09	1563	6.7	22.8	3.2	1.0	98.2
62.01	1562	6.7	25.8	3.0	0.0	93.5
62.03	1557	6.6	24.8	3.4	0.0	96.1
62.06	1559	6.4	24.3	3.0	0.0	96.5
62.10	1561	6.5	22.8	3.0	0.0	96.9
*63.08	1562	6.9	28.0	3.2	0.7	95.1
63.01	1549	6.7	27.5	2.8	0.0	93.3
63.04	1562	6.8	28.8	3.1	0.0	92.9

*Recycle Test

Table 4-3

PERCENTAGE OF TEMPERATURE RISE IN FREEBOARD

Test No.	*$\Delta T = T_{FB} - T_B$	$\Delta T/T_B \times 100$
62.01	69	4.4
62.02	79	5.0
62.03	66	4.2
62.04	54	3.3
62.05	-17	-.97
62.06	112	7.2
62.07	64	4.1
62.08	131	8.6
62.09	22	1.4
62.10	100	6.4
63.01	25	1.6
63.02	24	1.5
63.03	60	3.9
63.04	26	1.7
63.05	17	1.0
63.06	11	0.64
63.07	131	8.5
63.08	34	2.2
63.09	100	6.4
64.01	89	6.0

---

*T_{FB} = Freeboard temperature (highest of Locations No. 1, 2 and 3)

T_B = Bed temperature

Section 5

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

This research effort was successful in demonstrating the feasibility of combusting a high-solids (60% - 70%), coal-water slurry in a fluidized bed. To burn thickener underflow, additional heat input (in the form of supplemental coal feed) was required to sustain stable combustion and prevent defluidization due to agglomeration of bed material. Approximately one-third of the total thermal input was contributed by the coal feed.

The parametric testing revealed some relationships between performance and various operating parameters. For the most part, the trends that were established were in agreement with trends developed through years of experience with fluidized-bed coal combustion.

Combustion

In general, combustion efficiency was slightly higher for the Carbogel beneficiated coal-water slurry than for the Scotia-Liquicoal unbeneficiated slurry. Combustion efficiency was affected by bed temperature and superficial gas velocity, although the data were scattered. The reasons for the scatter are not obvious from test data acquired in this program, but we speculate that the degree of agglomeration of slurry droplets in the bed has a significant effect on combustion. As expected, recycle of cyclone fly ash resulted in improved combustion efficiency. CO emissions correlated well with bed temperature and superficial gas velocity. Finally, the combustion efficiency achieved was at least as good or better than that attained when firing bituminous coal under similar conditions.

Sulfur Capture

The calcium-to-sulfur feed ratio and bed temperature had the greatest effect on sulfur capture. Limestone particle size also affects sulfur capture but was not a variable in this study. Sulfur capture was better for the unbeneficiated

Scotia-Liquicoal slurry than for the Carbogel beneficiated slurry. This occurred because the sulfur concentration of the unbeneficiated slurry was much higher, producing a higher in-bed concentration of SO_2. Since the driving force behind sulfation is the SO_2 concentration, the higher concentration resulted in better sulfation efficiency.

Lime utilization was examined and found to be a function of the in-bed, solid-retention time. Spent-bed lime utilization was in the range of 30% - 40%.

NO_x Emissions

The parameters that were found to have a significant effect on NO_x emissions were bed temperature, the concentration of CO in the flue gas, and the amount of solid carbon in the carry-over. NO_x levels increased with increasing bed temperature. This is due to an increased coal devolatilization rate at higher temperature, which increases the rate at which volatile nitrogen compounds undergo oxidation. As the CO level in the flue gas increases, conditions in the bed become more reducing; this favors NO_x reduction.

Also, the decrease in NO_x emissions as the percentage of carbon in the carry-over increased is caused by a heterogeneous reaction that occurs between NO and carbon in the presence of CO in the freeboard region. The results support the findings of Chan [4], who studied the NO-carbon reaction.

Summary

Fluidized-bed combustion offers potential advantages over combusting coal-water slurry in a conventional burner. While fine atomization and optimum burner design are essential to achieving good combustion in a conventional system, they are not necessary in a fluidized-bed combustor. In fact, the method of injecting slurry into a fluidized bed is relatively simple, and combustion efficiency in the range of 98% can be achieved with recycle. Also, the results of this research effort indicate that a fluidized-bed combustor can operate almost equally as well with unbeneficiated slurry as with beneficiated fuel.

Finally, fluidized-bed combustion is a feasible method of incinerating thickener underflow, but only if support fuel is used to supply supplemental heat input. Auxiliary heat input is needed because of problems with bed agglomeration, which is caused by the high moisture content in the bed.

RECOMMENDATIONS

Because of favorable results obtained during this test program, further work in combustion of slurries in a fluidized bed is recommended. The following are four major areas that should be investigated:

- Agglomeration of slurry droplets in the bed. Because feed size has a significant effect on combustion, the feeding probe should be designed to produce an optimum droplet size. The optimum size of a droplet would result in the least amount of carbon lost to carryover. Different annular air velocities could be tested to determine their effect on droplet size.
- In some cases, because elutriated carbon loss is high, lower superficial velocities or a deeper bed should be considered to achieve better combustion efficiency.
- In fluidized-bed coal combustion, a major question in the design of large units is the number of feed locations needed to achieve good fuel distribution in the bed. From experience with firing fuel oil and very fine solid fuels, we feel that the number of feed locations required per unit area may be greater for slurry than for crushed coal. It will be necessary to quantify feedpoint spacing if large CWS-burning units are to be designed.
- Before an ambitious test program is undertaken to address these areas, a conceptual study of a commercial-scale, CWS-burning FBC is recommended to evaluate the economics of the system. For instance, there will be a trade-off between the additional cost of slurry preparation and the potential savings in coal transport expenses and possible simplification of the fuel feed system. (Pumping coal-water slurry may be less expensive than pneumatic transport of coal.) Also, in the case of thickener underflow, the initial capital cost and the operating cost of an FBC incinerator must be compared with present disposal expenses.

Section 6

REFERENCES

1. Ke-fa Cen, et al., "Combustion and Gasification of Coal-Water Slurry in Fluidized Beds," Proceedings of the 7th International Conference on Fluidized-Bed Combustion, Volume 1, 1982, pp. 253 - 263.

2. "6- x 6-ft. Atmospheric Fluidized-Bed Combustion Development Facility, 1980 Test Results," Electric Power Research Institute, EPRI CS-3115, Project 718-2, June 1983.

3. J. M. Beer, "Nitrogen Oxides Formation and Destruction in Fluidized Coal Combustion," Fluidized-Bed Combustion and Heat Transfer Continuing Education Course, Stanford University, August 8 - 12, 1983.

4. L. K. Chan, "Kinetics of the Nitric-Oxide-Carbon Reaction Under Fluidized-Bed-Combustor Conditions," dissertation, M.I.T., Cambridge, Mass., 1980.

ACKNOWLEDGMENTS

The author wishes to thank the following B&W personnel who were instrumental in completing this study:

- J. W. Vick, E. D. Daum, and and J. M. McCoury were responsible for the smooth operation of the pilot plant.
- J. T. Tang, T. A. Morris, and J. N. Duqum provided direction and guidance in data reduction and analysis.
- J. L. Basar was responsible for document preparation.

Thanks also go to I. T. Lau of the Canadian Department of Energy, Mines, and Resources for the valuable help and information he provided for the test program.

Appendix A

CHEMICAL ANALYSIS

Test Series 62 -- Carbogel Beneficiated CWS . . . . Page A-1

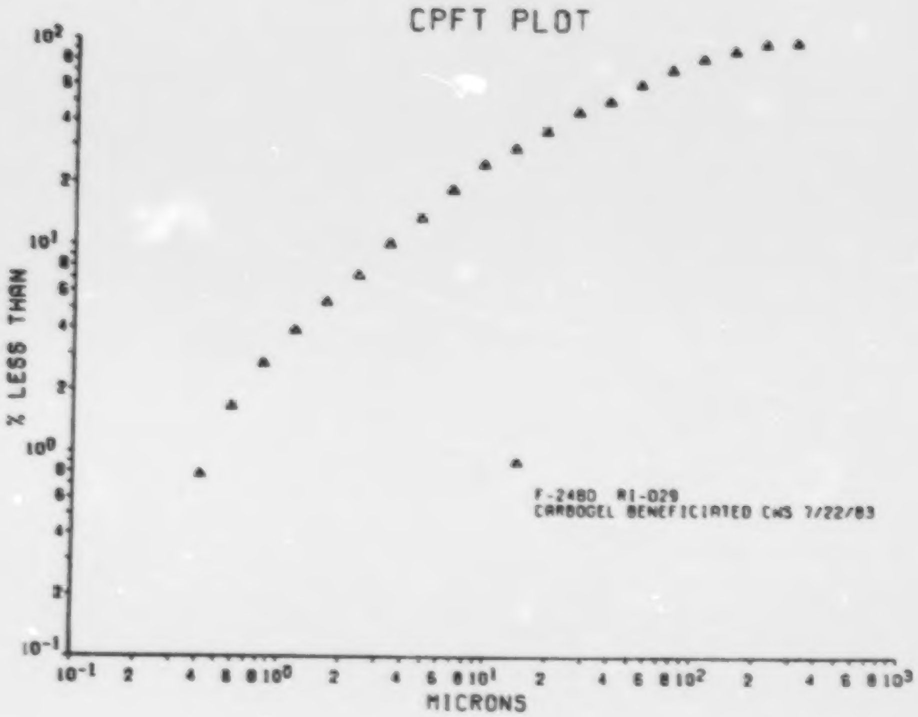
Test Series 63 -- Scotia-Liquicoal Unbeneficiated CWS . . . . Page A-34

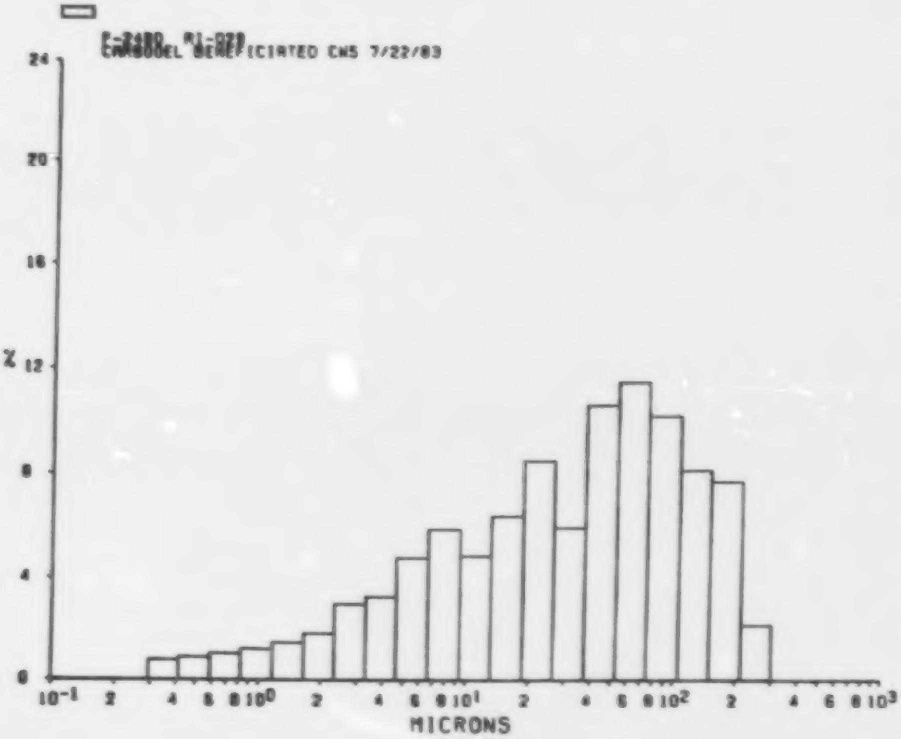
Test Series 64 -- Thickener Underflow . . . . Page A-56

TEST SERIES 62 -- CARBOGEL BENEFICIATED CWS

Sample No.	F-2480	
Description	Carbogel Beneficiated CWS	
Basis	As Received	Dry
Total Moisture, %	27.90	--
Solids	72.10	--
Proximate Analysis, %		
Moisture	27.90	--
Volatile Matter	27.71	38.43
Fixed Carbon	43.35	60.13
Ash	1.04	1.44
Gross Heating Value		
Btu per Lb.	10960	15200
Btu per Lb. (M&A Free)	--	15420
Ultimate Analysis, %		
Moisture	27.90	--
Carbon	61.8	85.7
Hydrogen	3.9	5.4
Nitrogen	1.20	1.66
Sulfur	0.55	0.76
Ash	1.04	1.44
Oxygen (Difference)	3.61	5.04
Total	100.00	100.00

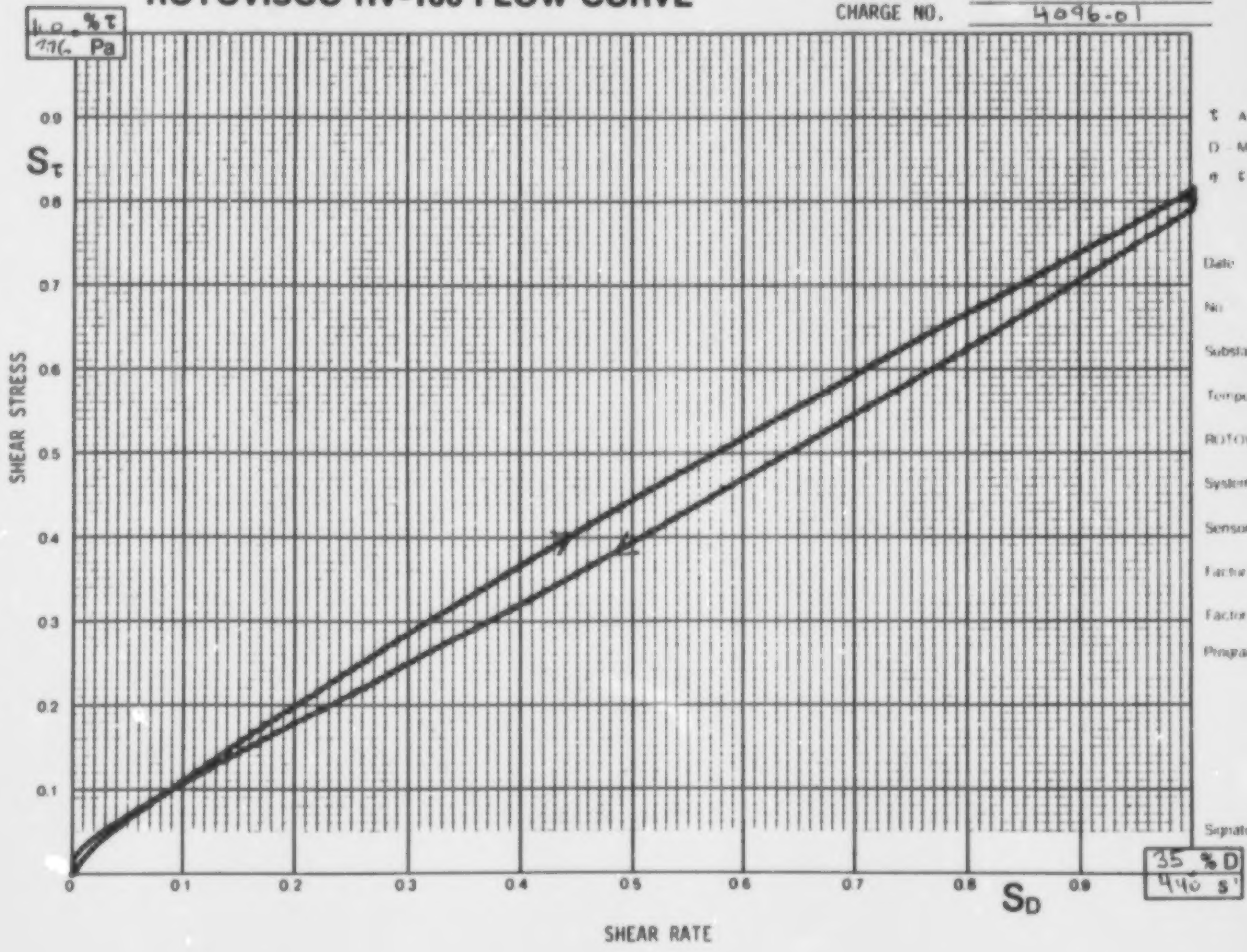
```
              F-2480  RI-029
              CARBOGEL BENEFICIATED CWS 7/22/83

   MICRONS    % LESS    DIFF

   300.00     100.00     2.12
   212.13      97.88     7.71
   150.00      90.16     8.15
   106.07      82.01    10.22
    75.00      71.79    11.49

    53.03      60.31    10.62
    37.50      49.69     5.97
    26.52      43.72     8.50
    18.75      35.23     6.38
    13.26      28.85     4.85

     9.38      24.00     5.90
     6.63      18.11     4.80
     4.69      13.31     3.25
     3.31      10.06     2.97
     2.34       7.09     1.80

     1.66       5.29     1.44
     1.17       3.85     1.18
     0.83       2.67     1.02
     0.59       1.65     0.88
     0.41       0.77     0.77

     0.29       0.00     0.00
     0.21
     0.15

              CS(CAL SURF AREA)=0.84 M**2/CM**3
              MMD(D43)=57.69 MICRONS
              SMD(D32)=7.16 MICRONS
```


CPFT PLOT
% LESS THAN
10^2
8
6
4
2
10^1
8
6
4
2
10^0
8
6
4
2
10^-1
10^-1 2 4 6 8 10^0 2 4 6 8 10^1 2 4 6 8 10^2 2 4 6 8 10^3
MICRONS
F-2480 RI-029
CARBOGEL BENEFICIATED CWS 7/22/83


F-2480 RI-029
CARBOGEL BENEFICIATED CWS 7/22/83
%
24
20
16
12
8
4
0
10^-1 2 4 6 8 10^0 2 4 6 8 10^1 2 4 6 8 10^2 2 4 6 8 10^3
MICRONS

SAMPLE NO. F-2480
SAMPLE TYPE CWS
% SOLIDS
CUSTOMER
CHARGE NO. 4096-01

ROTOVISCO RV-100 FLOW CURVE

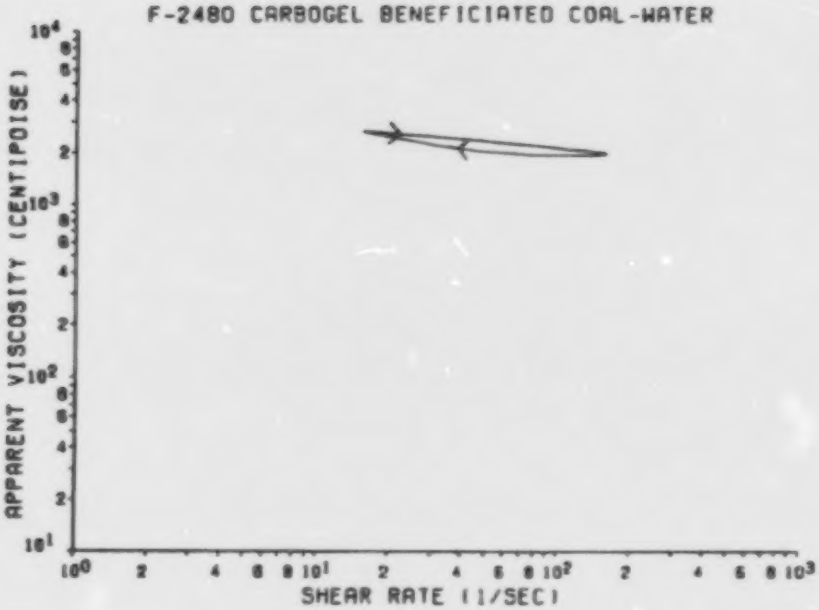


$\tau = A \cdot \%\tau \cdot S_\tau$ (Pa)
$D = M \cdot \%D \cdot S_D$ (s⁻¹)
$\eta = \tau / D$ (Pa·s)

Date 4-1-91
No.
Substance CWS
Temperature 74°F
ROTOVISCO RV 100
System
Sensor system MV II P
Factor A 3.76
Factor M 4.40
Program times
T_1 0.1
T_2 4.0
T_3 1.0
Signature RSD

F-2480 CARBOGEL BENEFICIATED COAL-WATER

SHEAR RATE (1/SEC)	ASCENDING VISCOSITY (CENTIPOISE)	DESCENDING VISCOSITY (CENTIPOISE)	SHEAR RATE (1/SEC)
15.4	2636.9	1928.8	154.0
30.8	2429.4	1918.0	138.6
46.2	2319.5	1907.5	123.2
61.6	2240.1	1911.4	107.8
77.0	2168.1	1912.6	92.4
92.4	2107.9	1923.9	77.0
107.8	2061.4	1953.2	61.6
123.2	2038.7	2026.5	46.2
138.6	2002.1	2185.2	30.8
154.0	1977.7	2636.9	15.4



Sample No. F-2542

Description Composite of 10 Coal Slurry Samples
F-2532 through F-2541

Basis	At Received	Dry
Total Moisture, %	28.51	--
Proximate Analysis, %		
Moisture	28.51	--
Volatile Matter	26.12	36.54
Fixed Carbon	44.32	61.99
Ash	1.05	1.47
Gross Heating Value		
Btu per Lb.	10,890	15,230
Btu per Lb. (M&A Free)	--	15,460
Ultimate Analysis, %		
Moisture	28.51	--
Carbon	60.94	85.24
Hydrogen	3.98	5.57
Nitrogen	1.15	1.61
Sulfur	0.50	0.70
Ash	1.05	1.47
Oxygen (Difference)	3.87	5.41
Total	100.00	100.00

Sample No. F-2542

Description Composite of 10 Coal
Slurry Samples
F-2532 thru F-2541

Ash Analysis (Spectrographic), %	
Silicon as SiO_2	34.19
Aluminum as Al_2O_3	21.82
Iron as Fe_2O_3	31.07
Titanium as TiO_2	1.46
Calcium as CaO	2.22
Magnesium as MgO	1.08
Sodium as Na_2O*	1.85
Potassium as K_2O*	3.61
Sulfur as SO_3	1.58
Phosphorus as P_2O_5	1.00

Sample No.	F-2532		F-2533	
Description	Coal Slurry, 1205, Test 62.1 8/4/83		Coal Slurry, 1610, Test 62.2 8/4/83	
Basis	As Received	Dry	As Received	Dry
Total Moisture, %	28.1	--	28.16	--
Solids, %	71.9	--	71.84	--
Carbon, %	61.1	85.0	61.1	85.1
Sulfur, %	0.54	0.75	0.55	0.77

Sample No.	F-2534		F-2535	
Description	Coal Slurry, 1138, Test 62.3 8/8/83		Coal Slurry, 1305, Test 62.4 8/8/83	
Basis	As Received	Dry	As Received	Dry
Total Moisture, %	28.5	--	28.4	--
Solids, %	71.5	--	71.6	--
Carbon, %	64.9	84.1	60.9	85.1
Sulfur, %	0.53	0.74	0.53	0.74

Sample No.	F-2536		F-2537	
Description	Coal Slurry, 1035, Test 62.5 8/9/83		Coal Slurry, 1309, Test 62.6 8/9/83	
Basis	As Received	Dry	As Received	Dry
Total Moisture, %	28.4	--	28.3	--
Solids, %	71.6	--	71.7	--
Carbon, %	60.9	85.1	60.8	84.8
Sulfur, %	0.56	0.78	0.55	0.77

Sample No.	F-2538		F-2539	
Description	Coal Slurry, 1030, Test 62.7 8/10/83		Coal Slurry, 1430, Test 62.8 8/10/83	
Basis	As Received	Dry	As-Received	Dry
Total Moisture, %	28.3	--	28.2	--
Solids, %	71.7	--	71.8	--
Carbon, %	60.8	84.8	60.4	84.8
Sulfur, %	0.54	0.75	0.51	0.71

Sample No.	F-2540		F-2541	
	Coal Slurry, 62.9		Coal Slurry, 62.10	
Basis	As Received	Dry	As Received	Dry
Total Moisture, %	28.2	--	29.0	--
Solid, %	71.8	--	71.0	--
Carbon, %	61.0	84.8	61.0	85.9
Sulfur, %	0.51	0.71	0.49	0.69

Sample No.	K-26564	K-26565	K-26566	K-26567	K-26568
Description	Cyclone Ash, 1230, Test 62.1 8/4/83	Cyclone Ash, 1630, Test 62.2 8/4/83	Cyclone Ash, 1130, Test 62.3 8/8/83	Cyclone Ash, 1430, Test 62.4 8/8/83	Cyclone Ash, 1030, Test 62.5 8/9/83
Moisture %	1.2	0.3	0.4	0.3	0.4
Ash, Dry, %	43.5	59.3	62.8	69.4	68.1
Calcium as CaO, Dry, %	15.4	32.4	31.9	46.2	29.7
*Sulfur as S, Dry, %	2.1	4.4	4.2	4.2	3.4
*Sulfur as SO_3, Dry, %	5.3	11.0	10.4	10.4	8.5
Carbonate as CO_2, Dry, %	1.9	4.1	3.3	2.4	1.1
**Carbon (Ult.). Dry, % (Corr. for CO_2)	51.5	34.8	32.4	27.0	30.3
Sizing					
% Through #16	100	100	100	100	100
#30	99.9	99.9	99.9	99.9	99.8
#50	98.8	92.0	97.6	99.0	98.2
#100	93.2	68.8	85.6	85.4	89.6
#200	79.9	49.6	69.9	67.7	76.2
#325	61.3	31.0	50.2	50.2	60.4

Sample No.	K-26569	K-26570	K-26571	K-26572	K-26573
Description	Cyclone Ash, 1330, Test 62.6 8/9/83	Cyclone Ash, 1030, Test 62.7 8/10/83	Cyclone Ash, 1430, Test 62.8 8/10/83	Cyclone Ash, 0930, Test 62.9 8/11/83	Cyclone Ash, 1330, Test 62.10 8/11/83
Moisture %	0.1	1.8	9.7	1.9	2.4
Ash, Dry, %	71.6	51.7	57.4	62.8	45.8
Calcium as CaO, Dry, %	34.8	26.3	27.3	26.3	14.6
*Sulfur as S, Dry, %	4.0	3.0	3.2	3.5	2.5
*Sulfur as SO_3, Dry, %	9.9	7.5	8.1	8.7	6.2
Carbonate as CO_2, Dry, %	2.2	2.6	4.6	4.4	1.3
**Carbon (Ult.). Dry, % (Corr. for CO_2)	32.7	40.7	31.9	29.1	49.6
Sizing					
% Through #16	100	100	100	100	100
#30	99.9	99.9	99.9	99.9	100
#50	98.6	98.5	99.3	99.8	99.9
#100	77.7	84.2	85.4	98.4	98.3
#200	58.4	59.7	63.8	89.0	90.6
#325	38.5	37.5	42.4	69.6	76.4

Sample No.	K-26574	K-26575	K-26576	K-26577	K-26578
Description	Baghouse Ash, 1230, Test 62.1 8/4/83	Baghouse Ash, 1645, Test 62.2 8/4/83	Baghouse Ash, 1130, Test 62.3 8/8/83	Baghouse Ash, 1530, Test 62.4 8/8/83	Baghouse Ash, 1030, Test 62.5 8/9/83
Moisture %	3.2	1.1	2.5	2.0	0.9
Ash, Dry, %	82.4	80.3	79.0	79.0	71.2
Calcium as CaO, Dry, %	16.3	17.9	18.4	18.4	24.8
*Sulfur as S, Dry, %	4.0	3.5	3.4	3.4	4.2
*Sulfur as SO_3, Dry, %	10.0	8.7	8.6	8.5	10.6
Carbonate as CO_2, Dry, %	3.1	1.8	2.1	2.8	1.8
**Carbon (Ult.). Dry, % (Corr. for CO_2)	12.0	15.6	16.2	16.4	24.4

Sample No.	K-26579	K-26580	K-26581	K-26582	K-26583
Description	Baghouse Ash, 1400, Test 62.6 8/9/83	Baghouse Ash, 1030, Test 62.7 8/10/83	Baghouse Ash, 1430, Test 62.8 8/10/83	Baghouse Ash, 1030, Test 62.9 8/11/83	Baghouse Ash, 1400, Test 62.10 8/11/83
Moisture %	2.4	1.2	1.9	0.5	1.1
Ash, Dry, %	74.5	76.0	77.1	77.5	77.7
Calcium as CaO, Dry, %	22.2	19.2	22.1	20.0	23.3
*Sulfur as S, Dry, %	3.2	3.4	3.6	3.5	3.2
*Sulfur as SO_3, Dry, %	8.1	8.5	9.0	8.7	7.9
Carbonate as CO_2, Dry, %	1.1	1.3	1.8	1.5	1.2
**Carbon (Ult.). Dry, % (Corr. for CO_2)	21.9	19.2	18.4	20.0	19.7

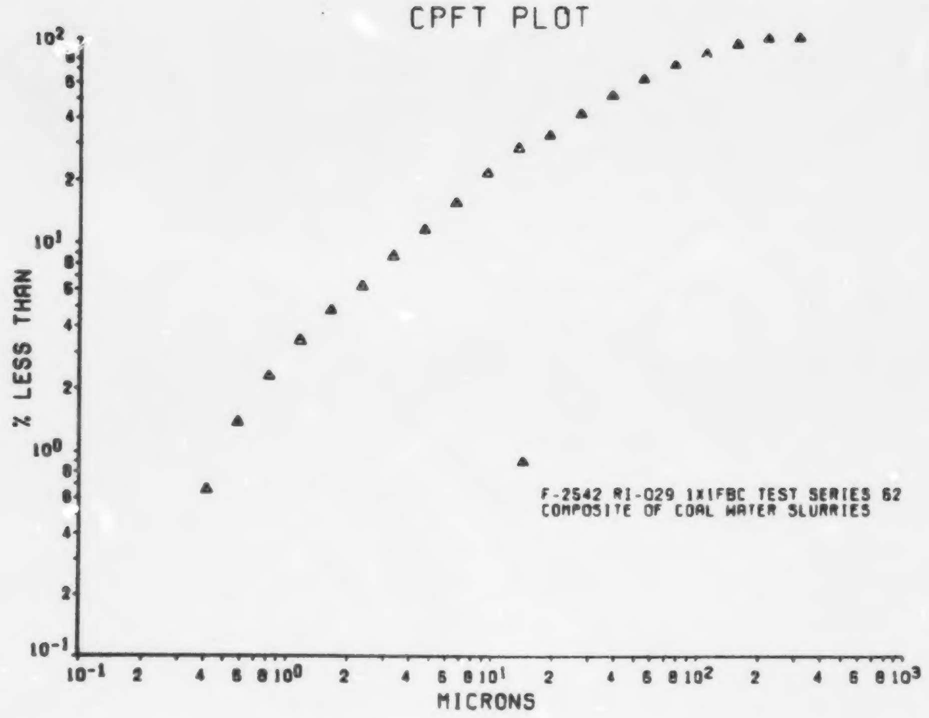
Sample No.	M-38344
Description	Reed Limestone, Test #6 8/26/83 from hopper (composite)
Moisture, %	0.2
Calcium as CaO, (Dry), %	50.1
Magnesium as MgO, (Dry), %	0.7
Carbonate as CO_2, (Dry), %	40.8
Calcium as $CACO_3$ (Dry), %	89.4
Sizing	
% Through 1/4"	100
#4	97.7
#8	85.1
#16	61.0
#30	42.6
#50	28.1
#100	17.8
#200	10.9
#325	6.7

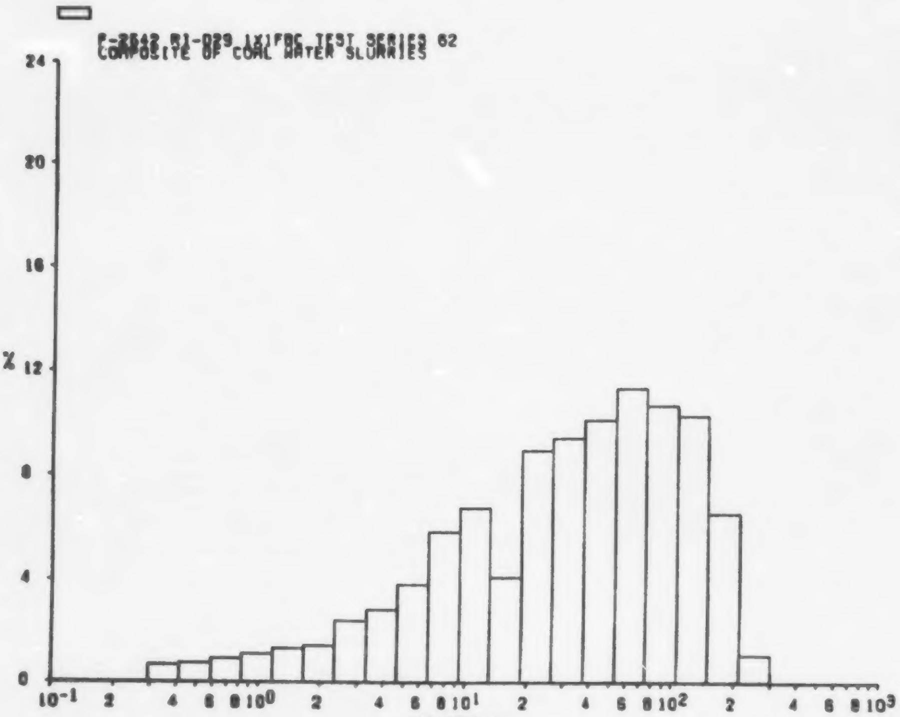
Sample No.	M-38345	M-38346	M-38347	M-38348	M-38349
Description	Bed Ash 12:30, Test 62.1 8/4/83	Bed Ash 1638, Test 62.2 8/4/83	Bed Ash 1130, Test 62.3 8/8/83	Bed Ash 1550, Test 62.4 8/8/83	Bed Ash 1030, Test 62.5 8/9/83
Moisture %	0.0	0.0	0.0	0.0	0.0
Ash, Dry, %	99.8	99.9	99.8	99.9	99.9
Calcium as CaO, Dry, %	51.6	52.1	52.5	53.9	56.2
*Sulfur as S, Dry, %	12.1	12.0	12.4	11.9	10.2
*Sulfur as S, Dry, %	30.3	30.1	30.9	29.7	25.6
Carbonate as CO_2, Dry, %	0.3	0.3	0.3	0.2	0.2
**Carbon (Ult.). Dry, % (Corr. for CO_2)	0.0	0.0	0.0	0.0	0.1
Sizing					
% Through 1/4"	99.2	100	99.4	100	99.4
# 4	96.7	98.6	98.0	99.2	98.8
# 8	73.7	81.7	88.7	86.2	94.6
# 16	35.4	48.3	59.8	49.9	76.0
# 30	7.2	13.4	20.0	11.9	33.5
# 50	0.2	0.1	0.5	0.2	1.5
#100	0.13	0.07	0.12	0.11	0.2
#200	0.09	0.05	0.09	0.09	0.12
#325	0.05	0.04	0.07	0.07	0.11

Sample No.	M-38350	M-38351	M-38352	M-38353	M-38354
Description	Bed Ash, 1430, Test 62.6 8/9/83	Bed Ash, 1030, Test 62.7 8/10/83	Bed Ash, 1432, Test 62.8 8/10/83	Bed Ash, 1030, Test 62.9 8/11/83	Bed Ash, 1422, Test 62.10 8/11/83
Moisture %	0.0	0.0	0.0	0.0	0.0
Ash, Dry, %	99.9	99.9	99.9	99.9	99.9
Calcium as CaO, Dry, %	54.8	54.8	54.8	53.9	53.9
*Sulfur as S, Dry, %	10.3	11.2	10.9	11.5	11.4
*Sulfur as S, Dry, %	25.8	28.1	27.3	28.8	28.6
Carbonate as CO_2, Dry, %	0.3	0.2	0.2	0.3	0.2
**Carbon (Ult.). Dry, % (Corr. for CO_2)	0.1	0.0	0.1	0.1	0.0
Sizing					
% Through 1/4"	100	100	99.6	100	100
# 4	99.6	99.3	99.1	99.0	99.3
# 8	94.1	88.7	90.5	83.9	87.6
# 16	65.5	53.9	62.5	35.4	49.1
# 30	21.7	14.4	21.6	5.4	10.2
# 50	0.4	0.2	0.8	0.2	0.2
#100	0.07	0.10	0.22	0.13	0.1
#200	0.05	0.06	0.20	0.11	0.08
#325	0.04	0.03	0.18	0.09	0.06

```
                 F-2542 RI-029 (X)FBC TEST SERIES 62
                 COMPOSITE OF COAL WATER SLURRIES

MICRONS    % LESS     DIFF

300.00     100.00      1.06
212.13      98.95      6.52
150.00      92.43     10.23
106.07      82.20     10.65
 75.00      71.54     11.29

 53.03      60.26     10.08
 37.50      50.18      9.41
 26.52      40.77      8.92
 18.75      31.85      4.09
 13.26      27.76      6.75

  9.38      21.01      5.85
  6.63      15.16      3.81
  4.69      11.35      2.83
  3.31       8.52      2.39
  2.34       6.13      1.42

  1.66       4.71      1.31
  1.17       3.39      1.10
  0.83       2.29      0.91
  0.59       1.38      0.73
  0.41       0.66      0.66

  0.29       0.00      0.00
  0.21
  0.15

           CS(CAL SURF AREA)=0.75 M**2/CM**3
           MMD(D43)=66.41 MICRONS
           SMD(D32)=8.02 MICRONS
```

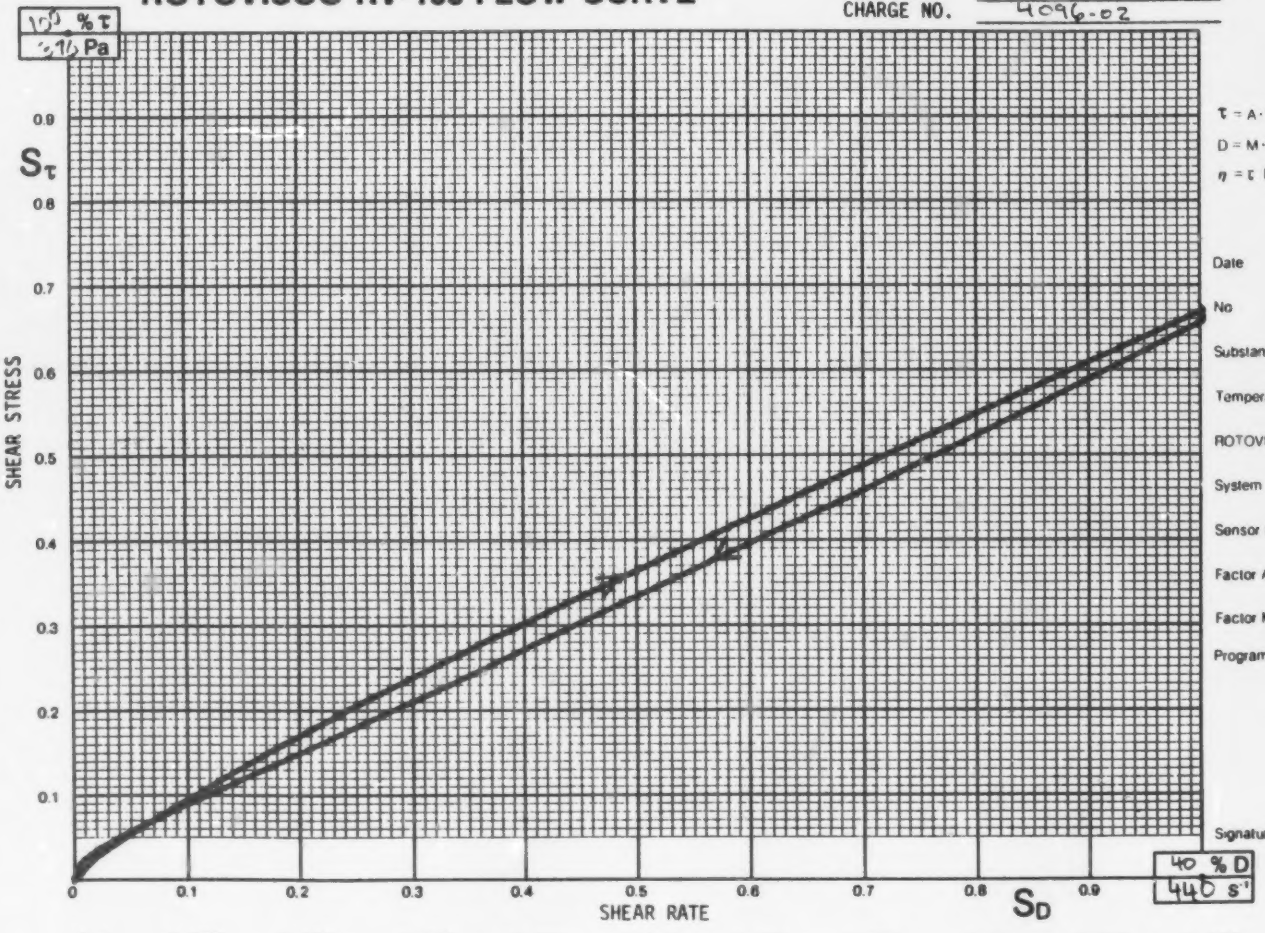
% + 300 microns = 0.01


CPFT PLOT
% LESS THAN
10^2
8
6
4
2
10^1
8
6
4
2
10^0
8
6
4
2
10^-1
10^-1 2 4 6 8 10^0 2 4 6 8 10^1 2 4 6 8 10^2 2 4 6 8 10^3
MICRONS
F-2542 RI-029 1X1FBC TEST SERIES 62
COMPOSITE OF COAL WATER SLURRIES


F-2542 RI-029 1X1FBC TEST SERIES 62
COMPOSITE OF COAL WATER SLURRIES
%
24
20
16
12
8
4
0
10^-1 2 4 6 8 10^0 2 4 6 8 10^1 2 4 6 8 10^2 2 4 6 8 10^3
MICRONS

SAMPLE NO. F-2532
SAMPLE TYPE 62% slurry
% SOLIDS
CUSTOMER
CHARGE NO. 4096-02

ROTOVISCO RV-100 FLOW CURVE

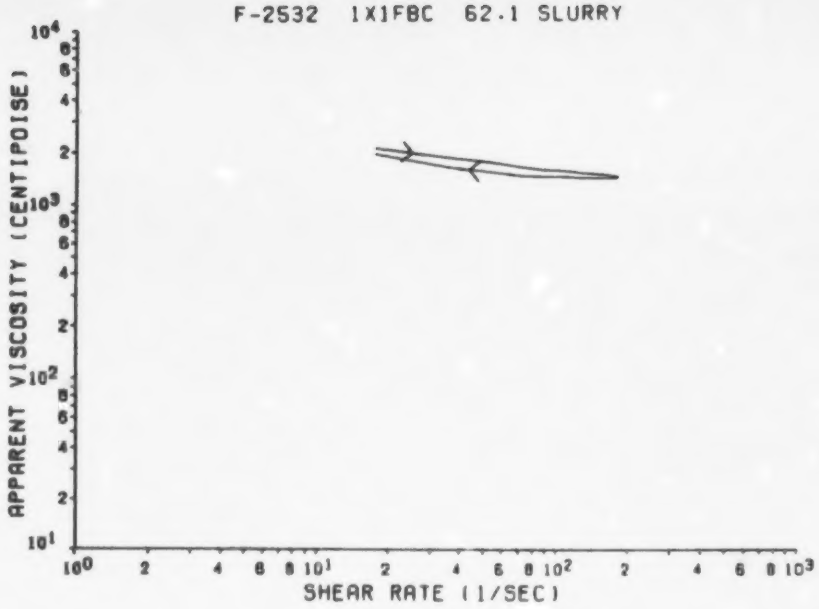


A =	0.097	0.170	0.239	0.301	0.364	0.427	0.488	0.549	0.610	0.688
D =	0.090	0.150	0.211	0.270	0.332	0.397	0.460	0.522	0.590	0.655

$\tau = A \cdot \%\tau \cdot S_\tau$ [Pa]
$D = M \cdot \%D \cdot S_D$ [s^{-1}]
$\eta = \tau / D$ [Pa·s]

Date	9-11-83
No	
Substance	CWS
Temperature	74°F
ROTOVISCO RV	100
System	
Sensor system	MV II P
Factor A	3.16
Factor M	4.40
Program times	
T_1	0.1
T_2	4.0
T_3	1.0
Signature	

F-2532 1X1FBC 62.1 SLURRY

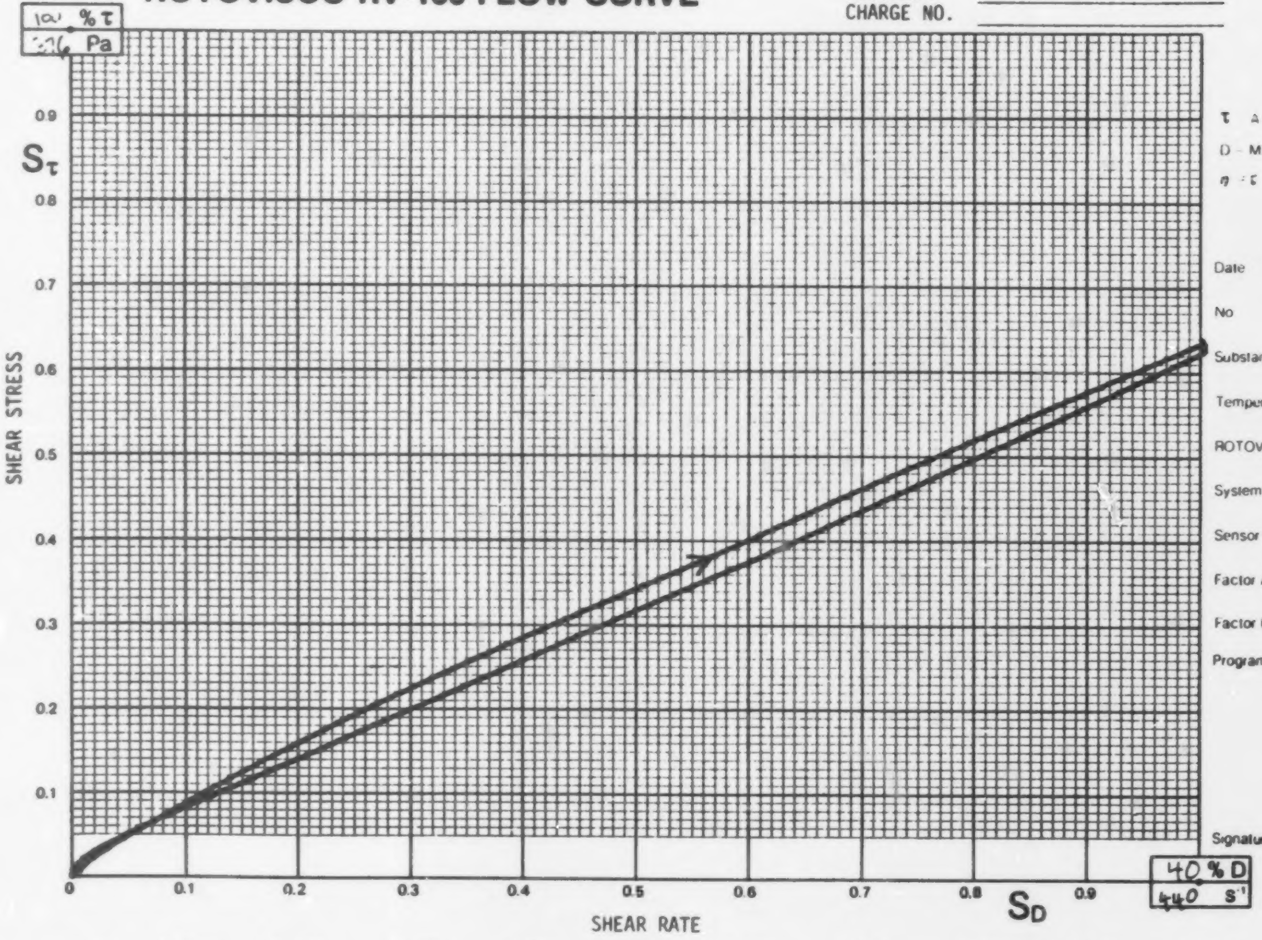


F-2532 1X1FBC 62.1 SLURRY

SHEAR RATE (1/SEC)	ASCENDING VISCOSITY (CENTIPOISE)	DESCENDING VISCOSITY (CENTIPOISE)	SHEAR RATE (1/SEC)
17.6	2072.3	1399.3	176.0
35.2	1815.9	1400.5	158.4
52.8	1702.0	1394.0	140.8
70.4	1607.6	1403.9	123.2
88.0	1555.3	1413.6	105.6
105.6	1520.4	1418.5	88.0
123.2	1489.4	1442.0	70.4
140.8	1466.1	1502.6	52.8
158.4	1448.0	1602.3	35.2
176.0	1427.1	1922.7	17.6

SAMPLE NO. F-2533
SAMPLE TYPE 62.2 Slurry
% SOLIDS
CUSTOMER
CHARGE NO.

ROTOVISCO RV-100 FLOW CURVE

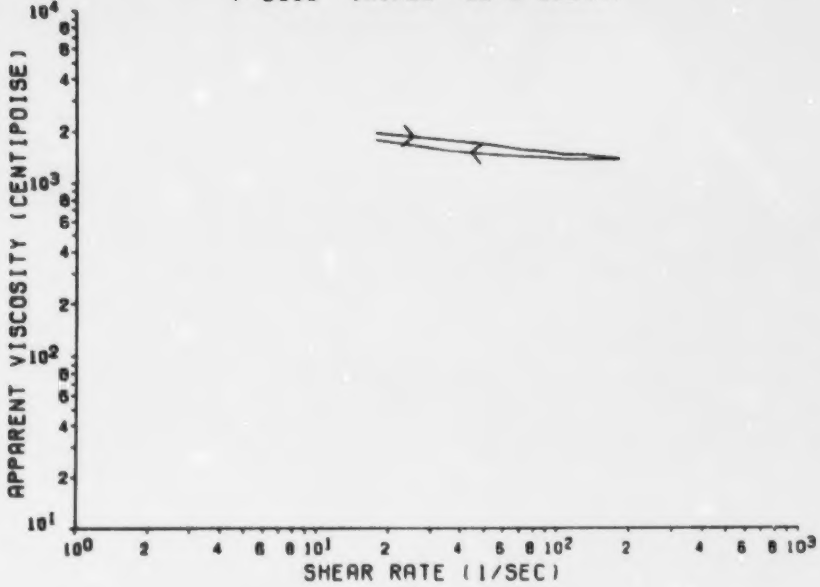


A =	0.089	0.160	0.225	0.284	0.343	0.400	0.462	0.520	0.578	0.633
D =	0.081	0.140	0.200	0.259	0.318	0.375	0.438	0.498	0.560	0.623

$\tau = A \cdot \%\tau \cdot S_\tau$ [Pa]
$D = M \cdot \%D \cdot S_D$ [s^{-1}]
$\eta = \tau / D$ [Pa·s]

Date	9-Aug
No	
Substance	CWS
Temperature	74°F
ROTOVISCO RV	100
System	
Sensor system	MV II P
Factor A	3.76
Factor M	4.40
Program times	
T_1	0.1
T_2	4.0
T_3	1.0
Signature	

F-2533 1X1FBC 62.2 SLURRY

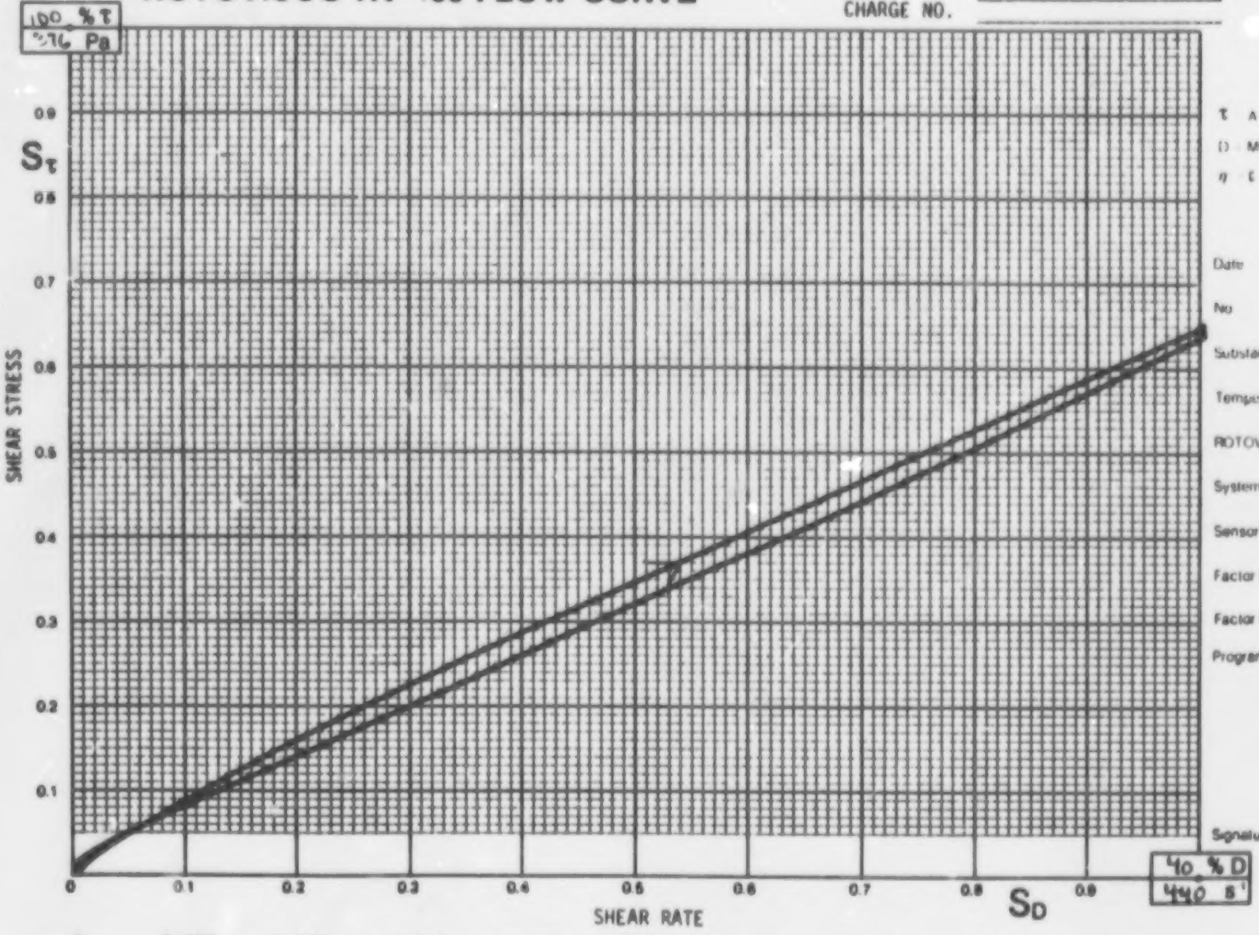


F-2533 1X1FBC 62.2 SLURRY

SHEAR RATE (1/SEC)	ASCENDING VISCOSITY (CENTIPOISE)	DESCENDING VISCOSITY (CENTIPOISE)	SHEAR RATE (1/SEC)
17.6	1901.4	1331.0	176.0
35.2	1709.1	1329.3	158.4
52.8	1602.3	1329.9	140.8
70.4	1516.8	1336.8	123.2
88.0	1465.5	1335.2	105.6
105.6	1424.2	1358.7	88.0
123.2	1410.0	1383.3	70.4
140.8	1388.6	1424.2	52.8
158.4	1372.0	1495.5	35.2
176.0	1352.3	1730.5	17.6

ROTOVISCO RV-100 FLOW CURVE

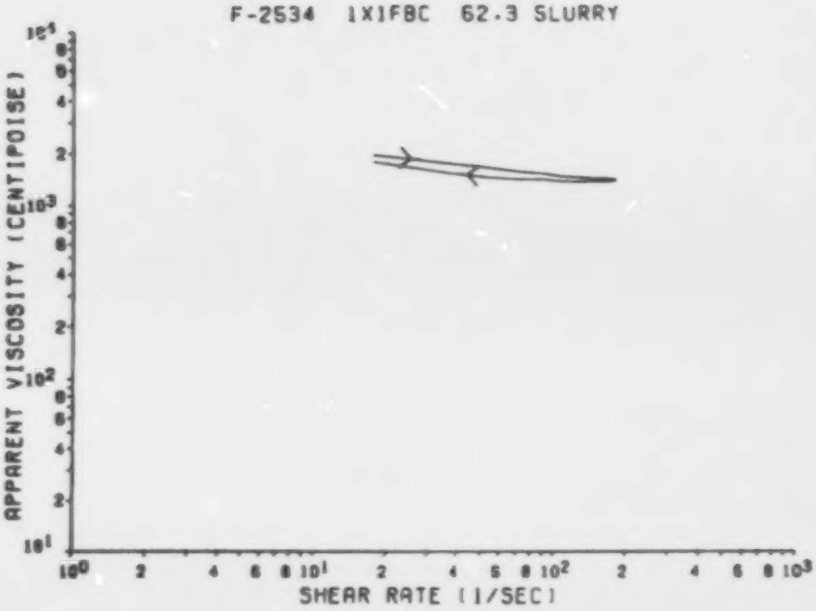
SAMPLE NO. F-2524
SAMPLE TYPE 62.3 Slurry
% SOLIDS
CUSTOMER
CHARGE NO.



$\tau = A \cdot \%\tau \cdot S_\tau$ [Pa]
$D = M \cdot \%D \cdot S_D$ [s^{-1}]
$\eta = \tau / D$ [Pa·s]

Date 9-[illegible]-83
No
Substance CWSF
Temperature 74°F
ROTOVISCO RV 100
System
Sensor system MV II P
Factor A 3.76
Factor M 4.40
Program times
T_1 0.1
T_2 4.0
T_3 1.0
Signature

A =	0.090	0.160	0.226	0.288	0.347	0.405	0.466	0.527	0.588	0.647
D =	0.082	0.141	0.200	0.260	0.322	0.380	0.447	0.505	0.570	0.636

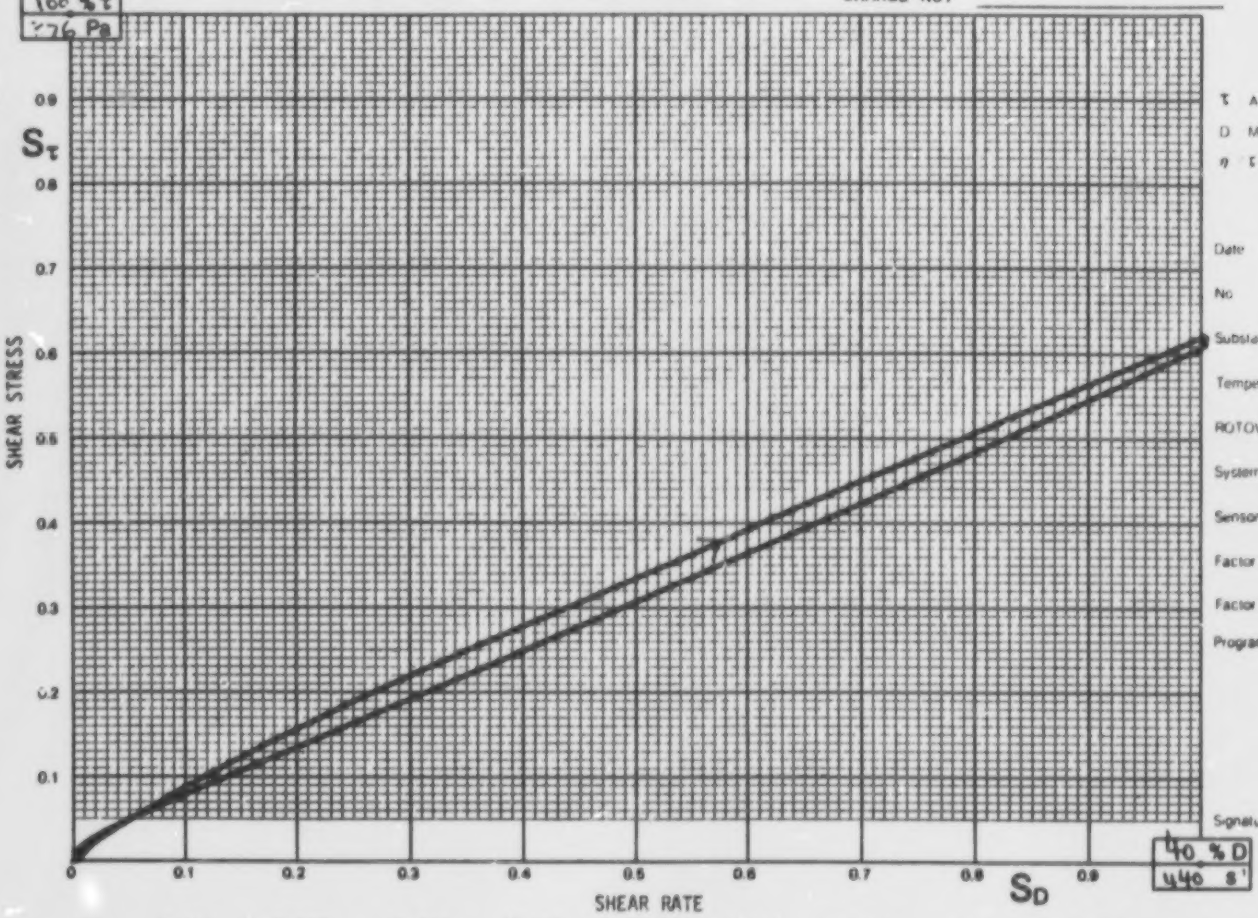


F-2534 1X1FBC 62.3 SLURRY

SHEAR RATE (1/SEC)	ASCENDING VISCOSITY (CENTIPOISE)	DESCENDING VISCOSITY (CENTIPOISE)	SHEAR RATE (1/SEC)
17.6	1922.7	1358.7	176.0
35.2	1719.8	1353.0	158.4
52.8	1609.4	1348.6	140.8
70.4	1538.2	1349.0	123.2
88.0	1482.6	1353.0	105.6
105.6	1442.0	1375.8	88.0
123.2	1422.2	1388.6	70.4
140.8	1407.3	1424.2	52.8
158.4	1395.8	1506.1	35.2
176.0	1382.2	1751.8	17.6

ROTOVISCO RV-100 FLOW CURVE

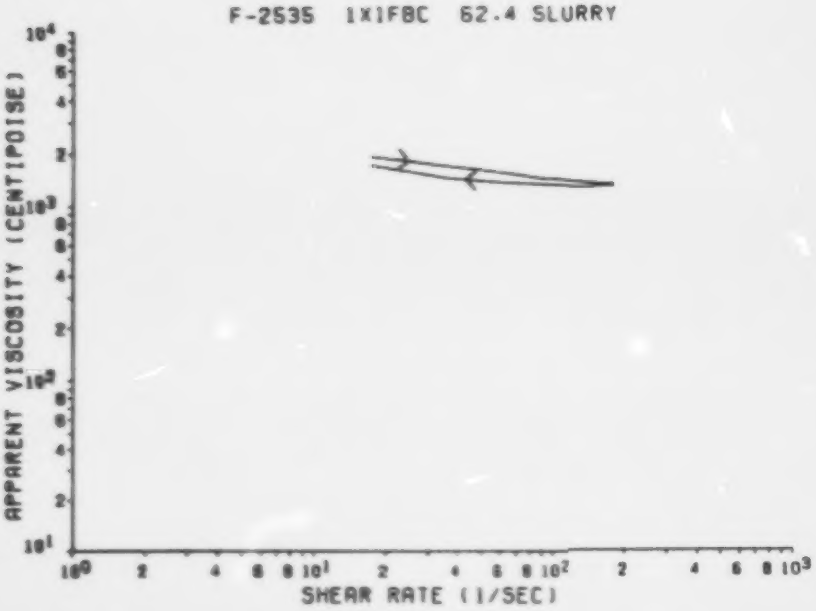
SAMPLE NO. F·2535
SAMPLE TYPE 62.4 [illegible]
% SOLIDS
CUSTOMER
CHARGE NO.



A =	0.089	0.157	0.220	0.279	0.334	0.392	0.450	0.505	0.562	0.620
D =	0.079	0.135	0.193	0.250	0.308	0.365	0.422	0.482	0.546	0.609

$\tau = A \cdot \tau \cdot S_\tau$ (Pa)
$D = M \cdot D \cdot S_D$ (s^{-1})
$\eta = \tau / D$ (Pa·s)

Date	5-19-83
No	[illegible]
Substance	C.W.S.
Temperature	76°F
ROTOVISCO RV	100
System	[illegible]
Sensor system	MV II P
Factor A	1.76
Factor M	4.40
Program times	
T_1	0.1
T_2	14.9
T_3	1.0
Signature	[illegible]

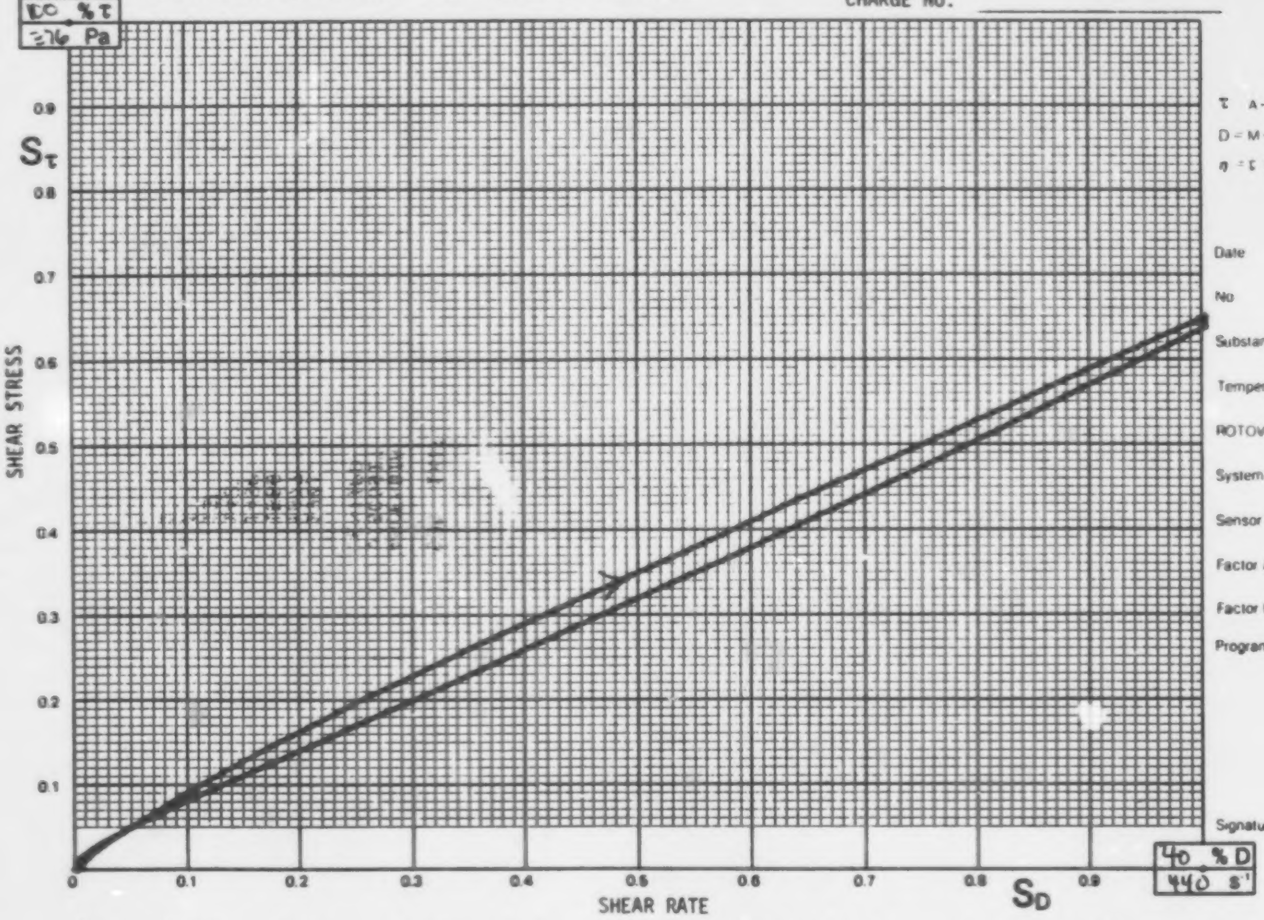


F-2535 1X1FBC 62.4 SLURRY

SHEAR RATE (1/SEC)	ASCENDING VISCOSITY (CENTIPOISE)	DESCENDING VISCOSITY (CENTIPOISE)	SHEAR RATE (1/SEC)
17.6	1901.4	1301.0	176.0
35.2	1677.0	1296.1	158.4
52.8	1506.7	1287.2	140.8
70.4	1490.1	1287.9	123.2
88.0	1427.1	1299.6	105.6
105.6	1395.8	1316.0	88.0
123.2	1373.4	1335.2	70.4
140.8	1348.6	1374.4	52.8
158.4	1334.0	1442.0	35.2
176.0	1324.5	1687.7	17.6

ROTOVISCO RV-100 FLOW CURVE

SAMPLE NO. F-2526
SAMPLE TYPE 62.5 S[illegible]
% SOLIDS
CUSTOMER
CHARGE NO.

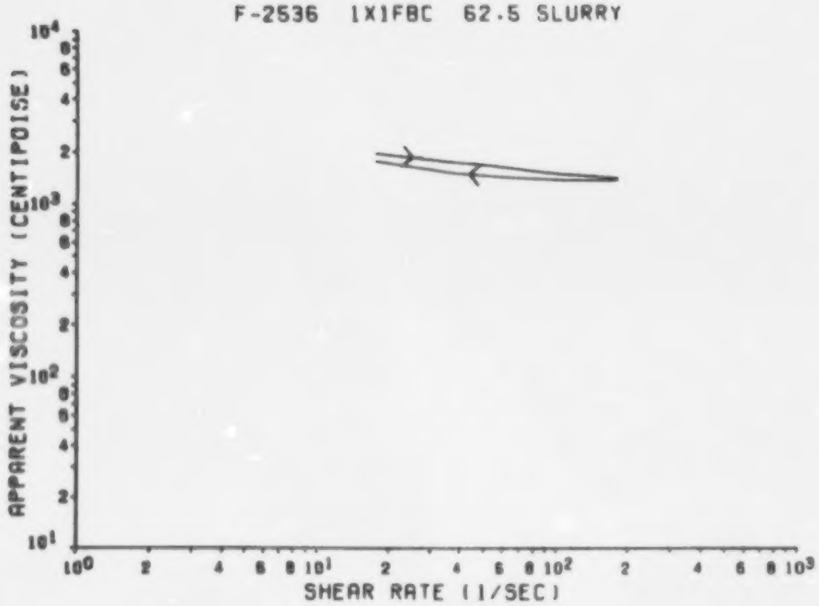


A =	0.090	0.161	0.229	0.290	0.350	0.409	0.470	0.529	0.589	0.649
B =	0.081	0.140	0.200	0.260	0.320	0.379	0.441	0.504	0.570	0.635

$\tau = A \cdot \%\tau \cdot S_\tau$ (Pa)
$D = M \cdot \%D \cdot S_D$ (s⁻¹)
$\eta = \tau / D$ (Pa·s)

Date	9-1?-83
No	
Substance	CU35
Temperature	76°F
ROTOVISCO RV	100
System	
Sensor system	MV2 P
Factor A	3.76
Factor M	4.40
Program times	
T_1	6.1
T_2	4.0
T_3	1.0
Signature	

F-2536 1X1FBC 62.5 SLURRY

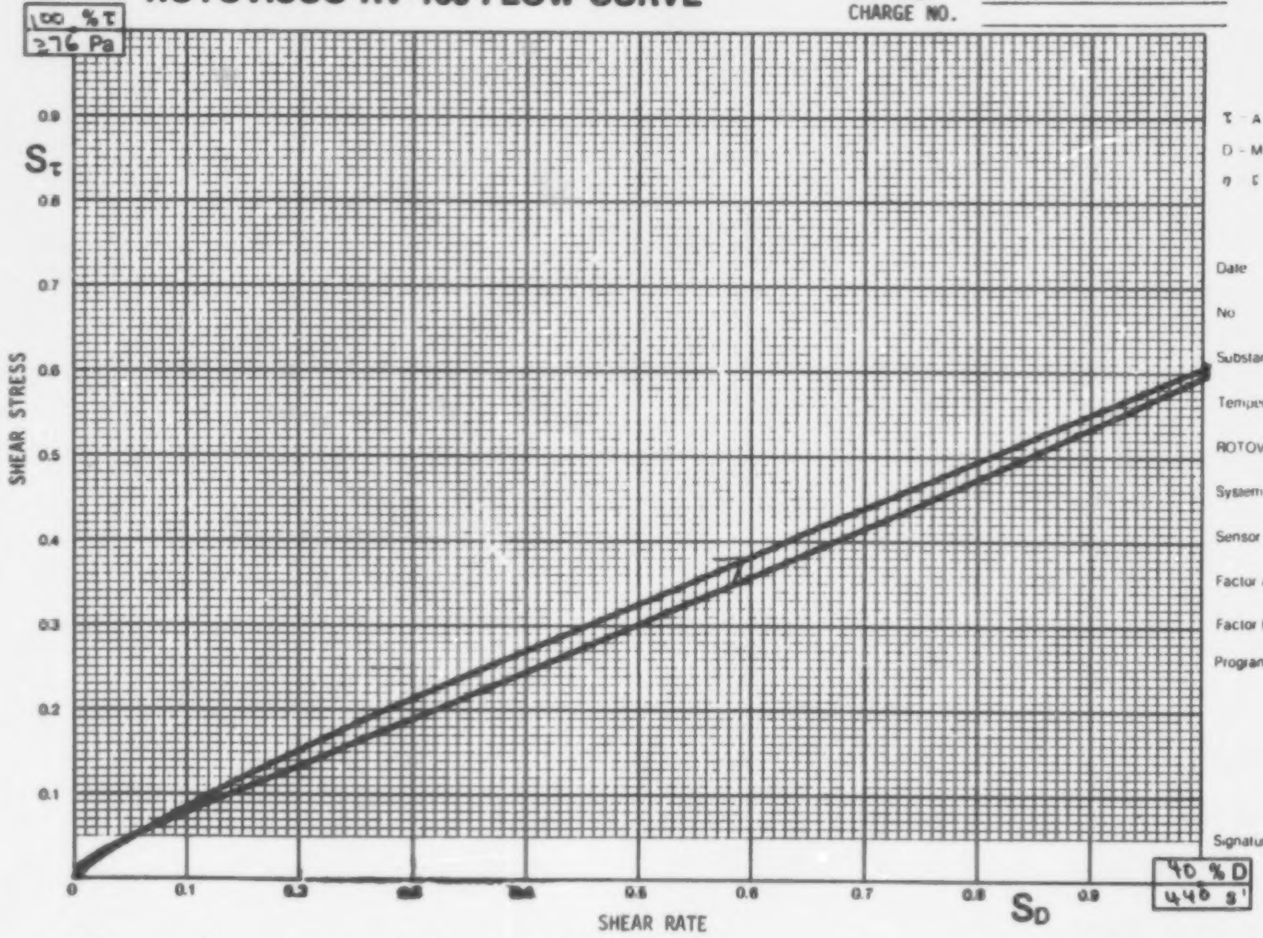


F-2536 1X1FBC 62.5 SLURRY

SHEAR RATE (1/SEC)	ASCENDING VISCOSITY (CENTIPOISE)	DESCENDING VISCOSITY (CENTIPOISE)	SHEAR RATE (1/SEC)
17.6	1922.7	1356.6	176.0
35.2	1719.8	1353.0	158.4
52.8	1630.8	1345.9	140.8
70.4	1548.9	1345.9	123.2
88.0	1495.5	1349.5	105.6
105.6	1456.3	1367.3	88.0
123.2	1434.4	1388.6	70.4
140.8	1412.7	1424.2	52.8
158.4	1398.1	1495.5	35.2
176.0	1386.5	1730.5	17.6

SAMPLE NO. F-2537
SAMPLE TYPE 62.6 Slurry
% SOLIDS
CUSTOMER
CHARGE NO.

ROTOVISCO RV-100 FLOW CURVE

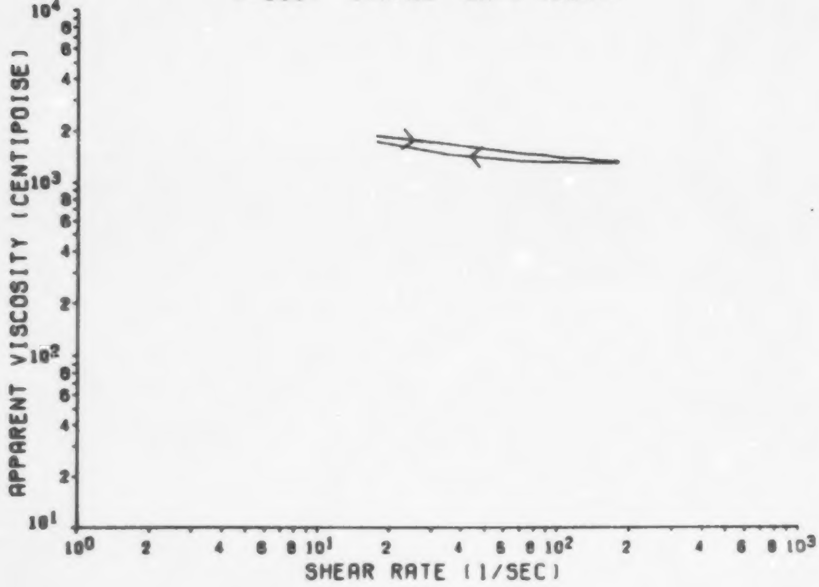


A =	0.085	0.152	0.212	0.270	0.326	0.381	0.440	0.495	0.550	0.605
D =	0.079	0.132	0.190	0.243	0.301	0.359	0.415	0.472	0.532	0.595

$\tau = A \cdot \%\tau \cdot S_\tau$ [Pa]
$D = M \cdot \%D \cdot S_D$ [s⁻¹]
$\eta = \tau / D$ [Pa·s]

Date	9-13-83
No	
Substance	Cws
Temperature	76 °F
ROTOVISCO RV	100
System	
Sensor system	[illegible]
Factor A	3.16
Factor M	4.48
Program times	
T_1	0.1
T_2	4.0
T_3	1.0
Signature	

F-2537 1X1FBC 62.6 SLURRY

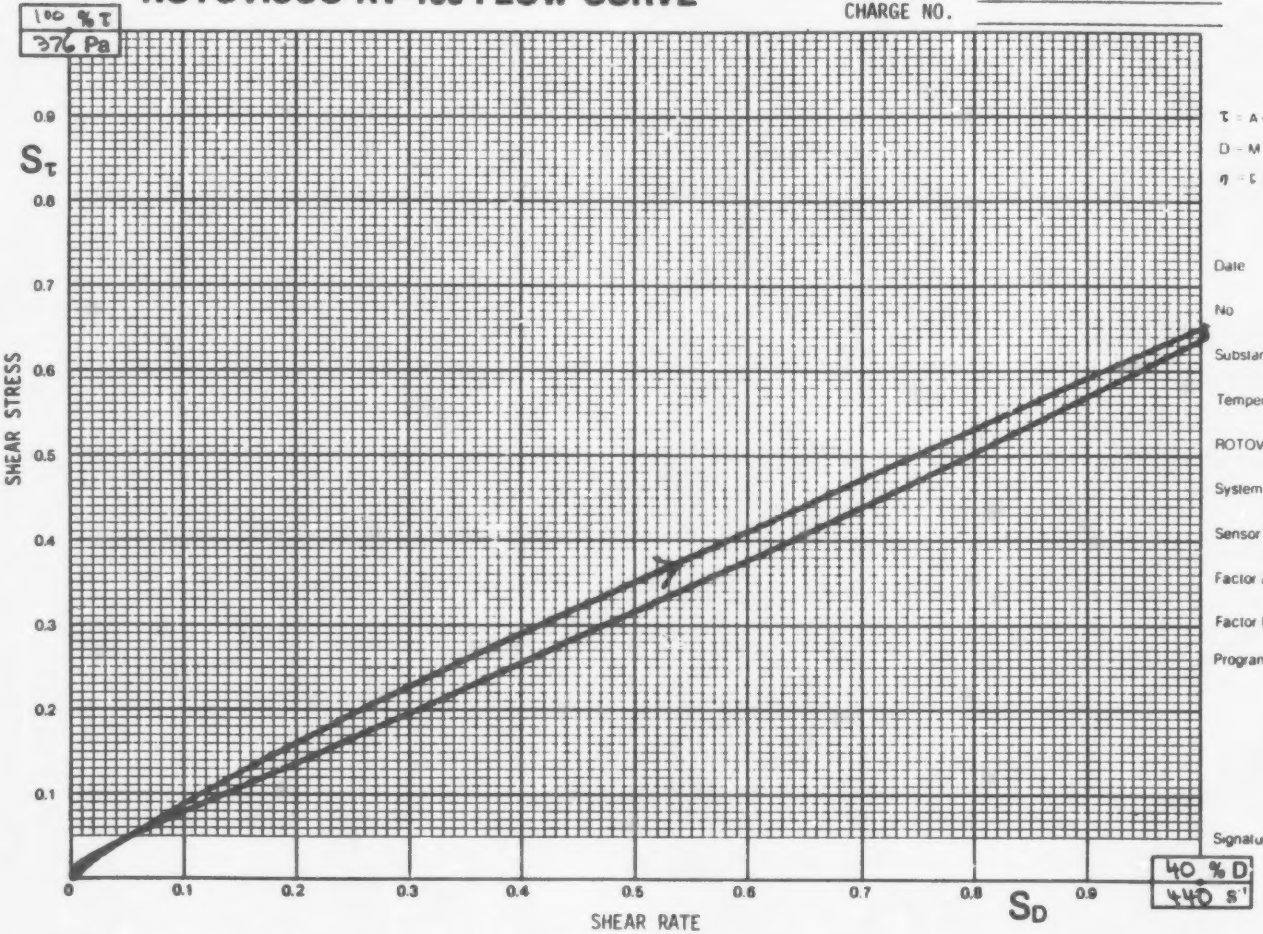


F-2537 1X1FBC 62.6 SLURRY

SHEAR RATE (1/SEC)	ASCENDING VISCOSITY (CENTIPOISE)	DESCENDING VISCOSITY (CENTIPOISE)	SHEAR RATE (1/SEC)
17.6	1815.9	1271.1	176.0
35.2	1623.6	1262.8	158.4
52.8	1509.7	1260.5	140.8
70.4	1442.0	1266.6	123.2
88.0	1392.9	1278.3	105.6
105.6	1356.6	1286.1	88.0
123.2	1342.9	1297.8	70.4
140.8	1321.9	1353.0	52.8
158.4	1305.6	1410.0	35.2
176.0	1292.5	1687.7	17.6

ROTOVISCO RV-100 FLOW CURVE

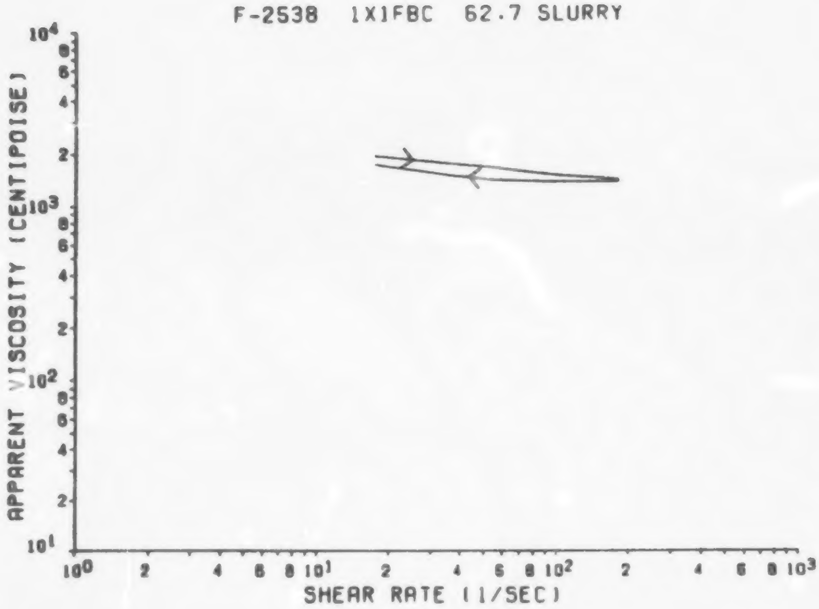
SAMPLE NO. F-2538
SAMPLE TYPE 62.7 Slurry
% SOLIDS
CUSTOMER
CHARGE NO.



$\tau = A \cdot \%\tau \cdot S_\tau$ [Pa]
$D = M \cdot \%D \cdot S_D$ [s^{-1}]
$\eta = \tau / D$ [Pa·s]

Date 9-19-83
No
Substance CWS
Temperature 74°F
ROTOVISCO RV 100
System
Sensor system MV P
Factor A 3.76
Factor M 4.40
Program times
T_1 0.1
T_2 5.0
T_3 1.0
Signature

A =	0.089	0.161	0.228	0.290	0.350	0.411	0.472	0.532	0.592	0.650
D =	0.079	0.138	0.195	0.255	0.316	0.377	0.440	0.503	0.570	0.635



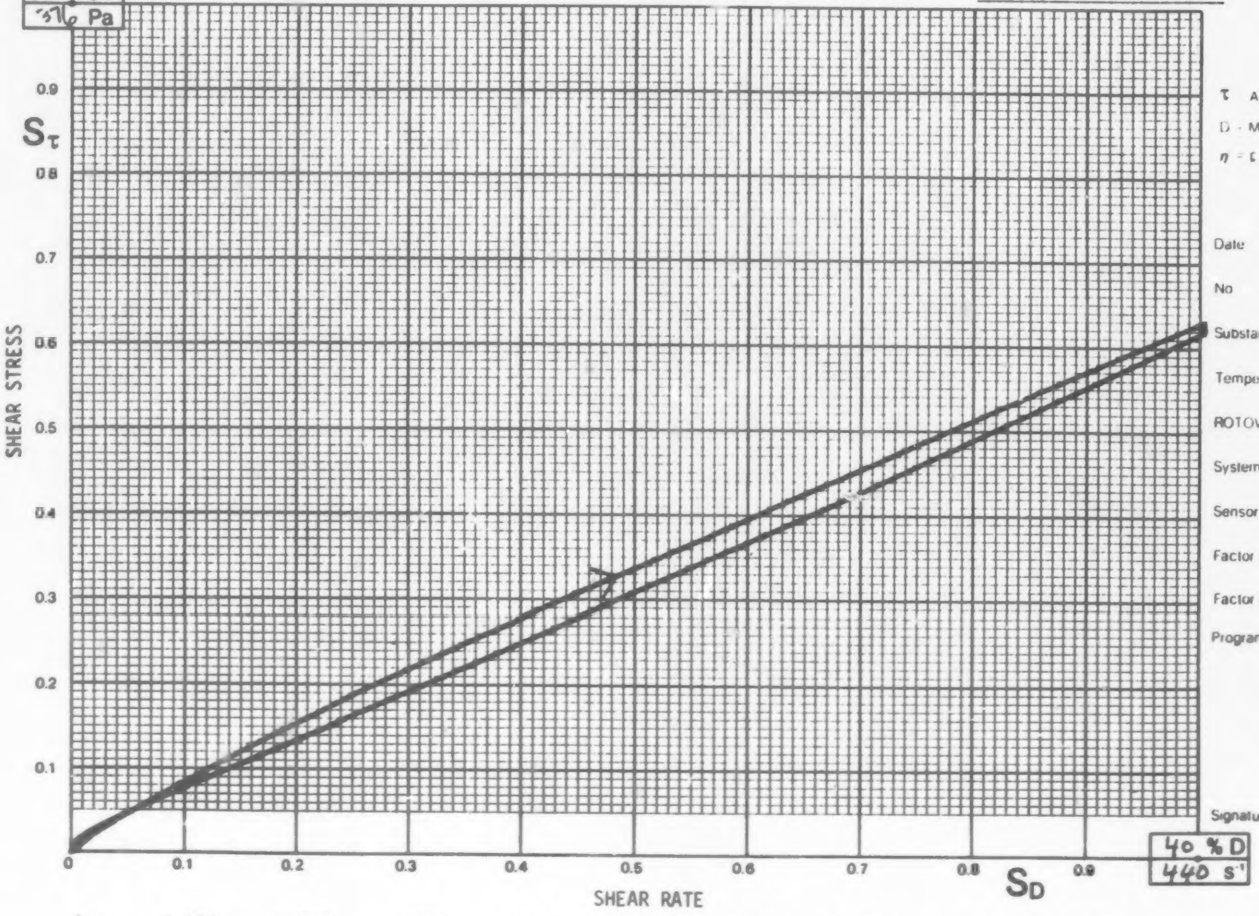
F-2538 1X1FBC 62.7 SLURRY

F-2538 1X1FBC 62.7 SLURRY

SHEAR RATE (1/SEC)	ASCENDING VISCOSITY (CENTIPOISE)	DESCENDING VISCOSITY (CENTIPOISE)	SHEAR RATE (1/SEC)
17.6	1901.4	1356.6	176.0
35.2	1719.8	1353.0	158.4
52.8	1623.6	1343.2	140.8
70.4	1548.9	1342.9	123.2
88.0	1495.5	1342.3	105.6
105.6	1463.4	1350.2	88.0
123.2	1440.5	1361.9	70.4
140.8	1420.7	1388.6	52.8
158.4	1405.3	1474.1	35.2
176.0	1388.6	1687.7	17.6

SAMPLE NO. F-2529
SAMPLE TYPE 62.8 Slurry
% SOLIDS
CUSTOMER
CHARGE NO.

ROTOVISCO RV-100 FLOW CURVE

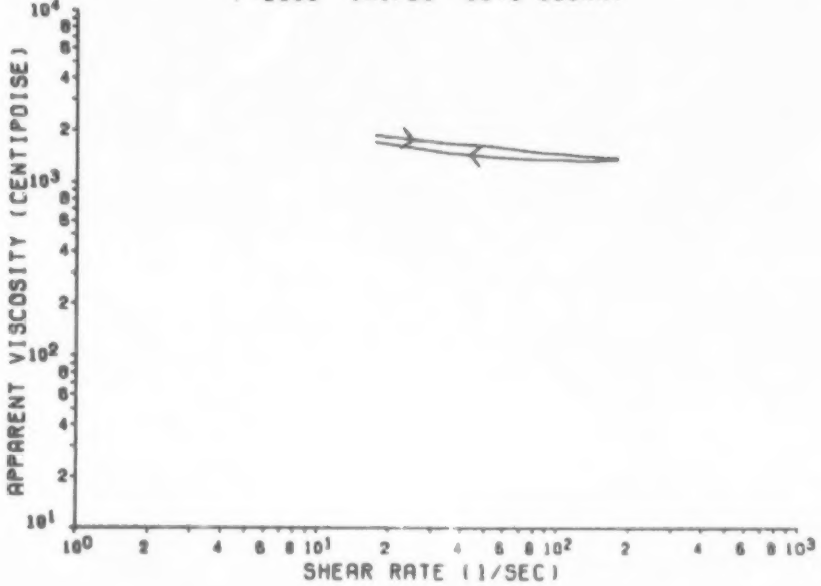


A =	0.085	0.153	0.219	0.278	0.337	0.396	0.454	0.511	0.570	0.630
D =	0.078	0.134	0.192	0.249	0.309	0.369	0.428	0.489	0.552	0.616

$\tau = A \cdot \%\tau \cdot S_\tau$ [Pa]
$D = M \cdot \%D \cdot S_D$ [s⁻¹]
$\eta = \tau / D$ [Pa·s]

Date 9-[illegible]-83
No
Substance CWS
Temperature 74°F
ROTOVISCO RV 100
System
Sensor system MV II P
Factor A 3.76
Factor M 4.40
Program times
T_1 2.1
T_2 1.0
T_3 1.0
Signature

F-2539 1X1FBC 62.8 SLURRY

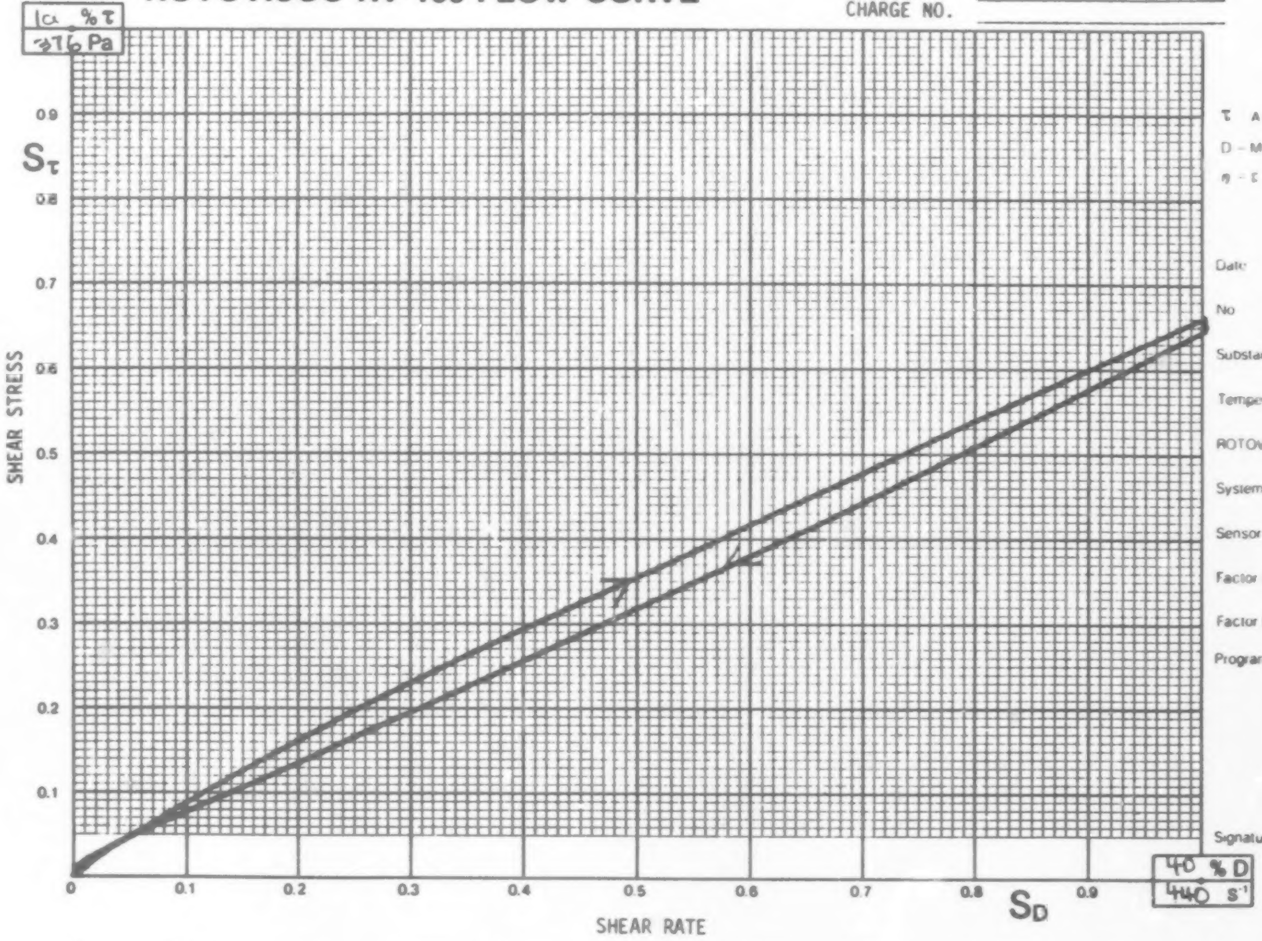


F-2539 1X1FBC 62.8 SLURRY

SHEAR RATE (1/SEC)	ASCENDING VISCOSITY (CENTIPOISE)	DESCENDING VISCOSITY (CENTIPOISE)	SHEAR RATE (1/SEC)
17.6	1815.9	1316.0	176.0
35.2	1634.3	1310.3	158.4
52.8	1559.5	1305.9	140.8
70.4	1484.8	1306.2	123.2
88.0	1439.9	1313.9	105.6
105.6	1410.0	1320.3	88.0
123.2	1385.6	1329.9	70.4
140.8	1364.6	1367.3	52.8
158.4	1353.0	1431.4	35.2
176.0	1345.9	1666.4	17.6

SAMPLE NO. F-2540
SAMPLE TYPE 62,9 [illegible]
% SOLIDS
CUSTOMER
CHARGE NO.

ROTOVISCO RV-100 FLOW CURVE

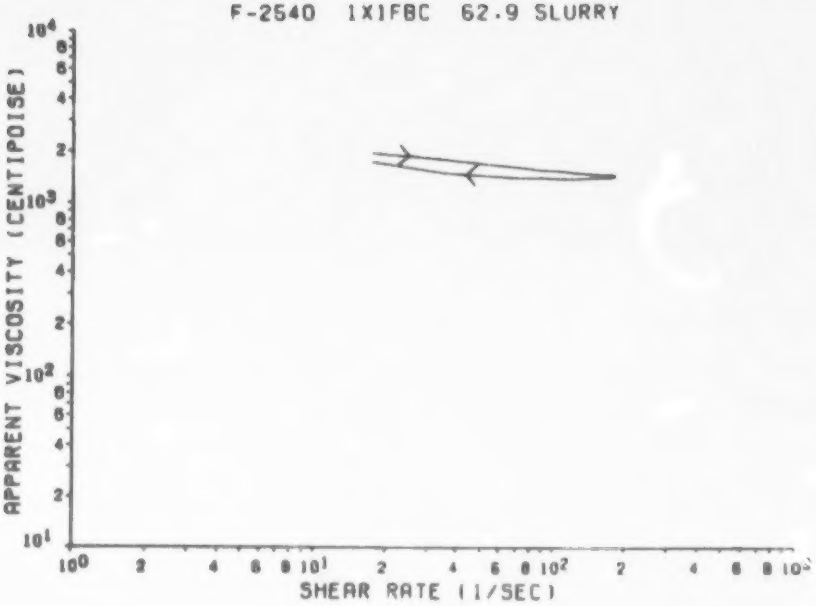


$\tau = A \cdot \%\tau \cdot S_\tau$ [Pa]
$D = M \cdot \%D \cdot S_D$ [s⁻¹]
$\eta = \tau : D$ [Pa·s]

Date 9-20-93
No
Substance CWS
Temperature 74°F
ROTOVISCO RV 100
System
Sensor system MV IIP
Factor A 3.16
Factor M 4.40
Program times
T_1 0.1
T_2 6.0
T_3 1.0
Signature

A =	0.089	0.152	0.230	0.294	0.355	0.418	0.478	0.540	0.600	0.660
D =	0.079	0.136	0.196	0.256	0.319	0.381	0.442	0.509	0.578	0.645

F-2540 1X1FBC 62.9 SLURRY

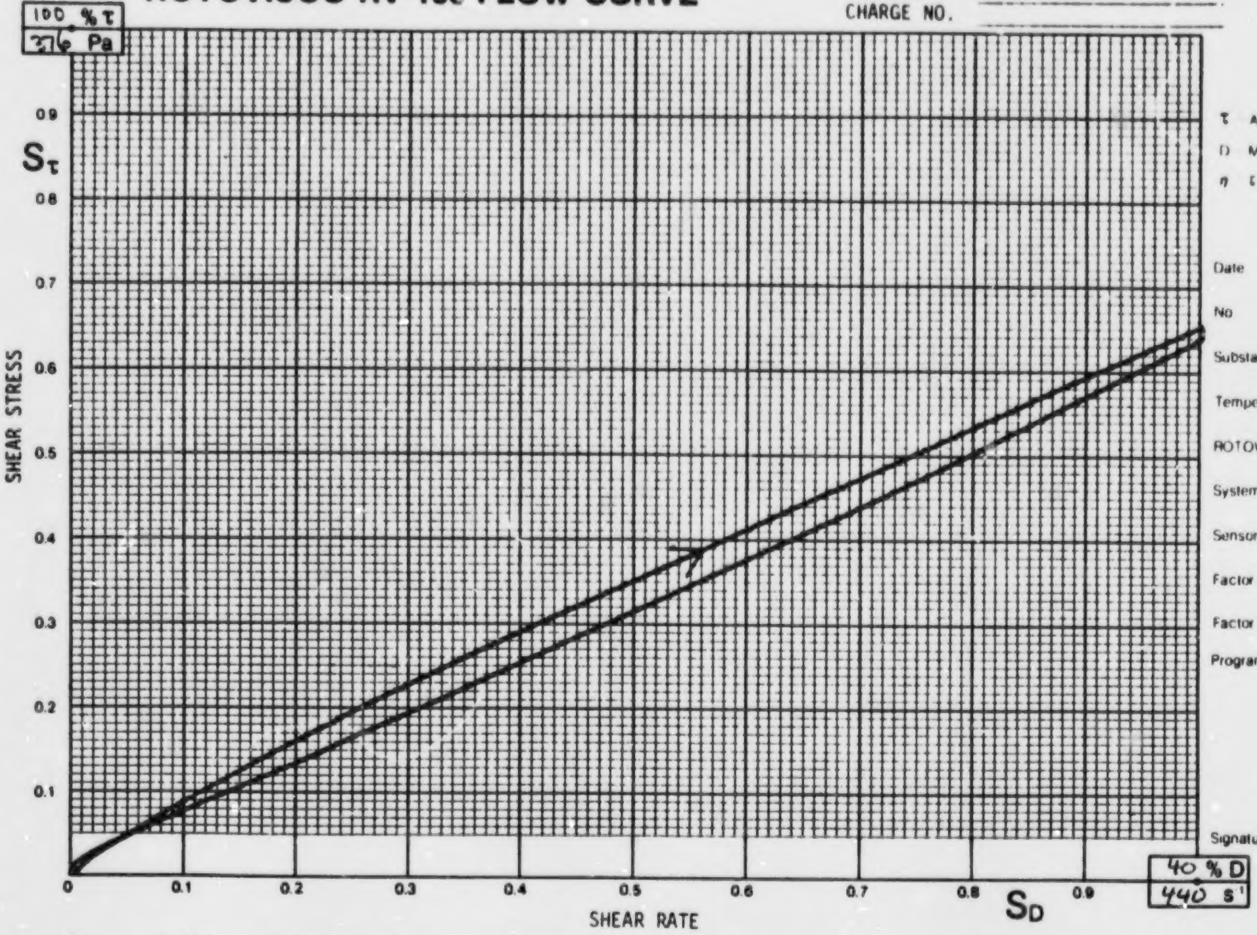


F-2540 1X1FBC 62.9 SLURRY

SHEAR RATE (1/SEC)	ASCENDING VISCOSITY (CENTIPOISE)	DESCENDING VISCOSITY (CENTIPOISE)	SHEAR RATE (1/SEC)
17.6	1901.4	1378.0	176.0
35.2	1730.5	1372.0	158.4
52.8	1637.9	1359.3	140.8
70.4	1570.2	1349.0	123.2
88.0	1516.8	1356.6	105.6
105.6	1488.3	1363.0	88.0
123.2	1458.8	1367.3	70.4
140.8	1442.0	1395.8	52.8
158.4	1424.2	1452.7	35.2
176.0	1410.0	1687.7	17.6

ROTOVISCO RV-100 FLOW CURVE

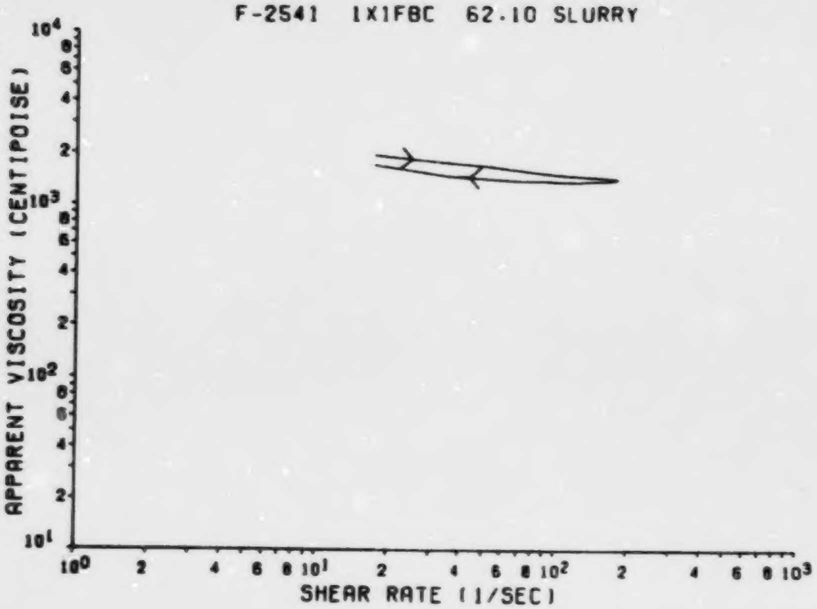
SAMPLE NO. F-2541
SAMPLE TYPE 62.10 [illegible]
% SOLIDS
CUSTOMER
CHARGE NO.



$\tau = A \cdot \%\tau \cdot S_\tau$ [Pa]
$D = M \cdot \%D \cdot S_D$ [s^{-1}]
$\eta = \tau / D$ [Pa·s]

Date 1-20-83
No
Substance CWS
Temperature 74°F
ROTOVISCO RV 100
System
Sensor system [illegible]
Factor A 3.76
Factor M 4.40
Program times
T_1 0.1
T_2 4.0
T_3 1.0
Signature

A =	0.089	0.160	0.228	0.290	0.351	0.411	0.472	0.532	0.593	0.651
D =	0.078	0.135	0.195	0.253	0.314	0.375	0.439	0.503	0.570	0.638

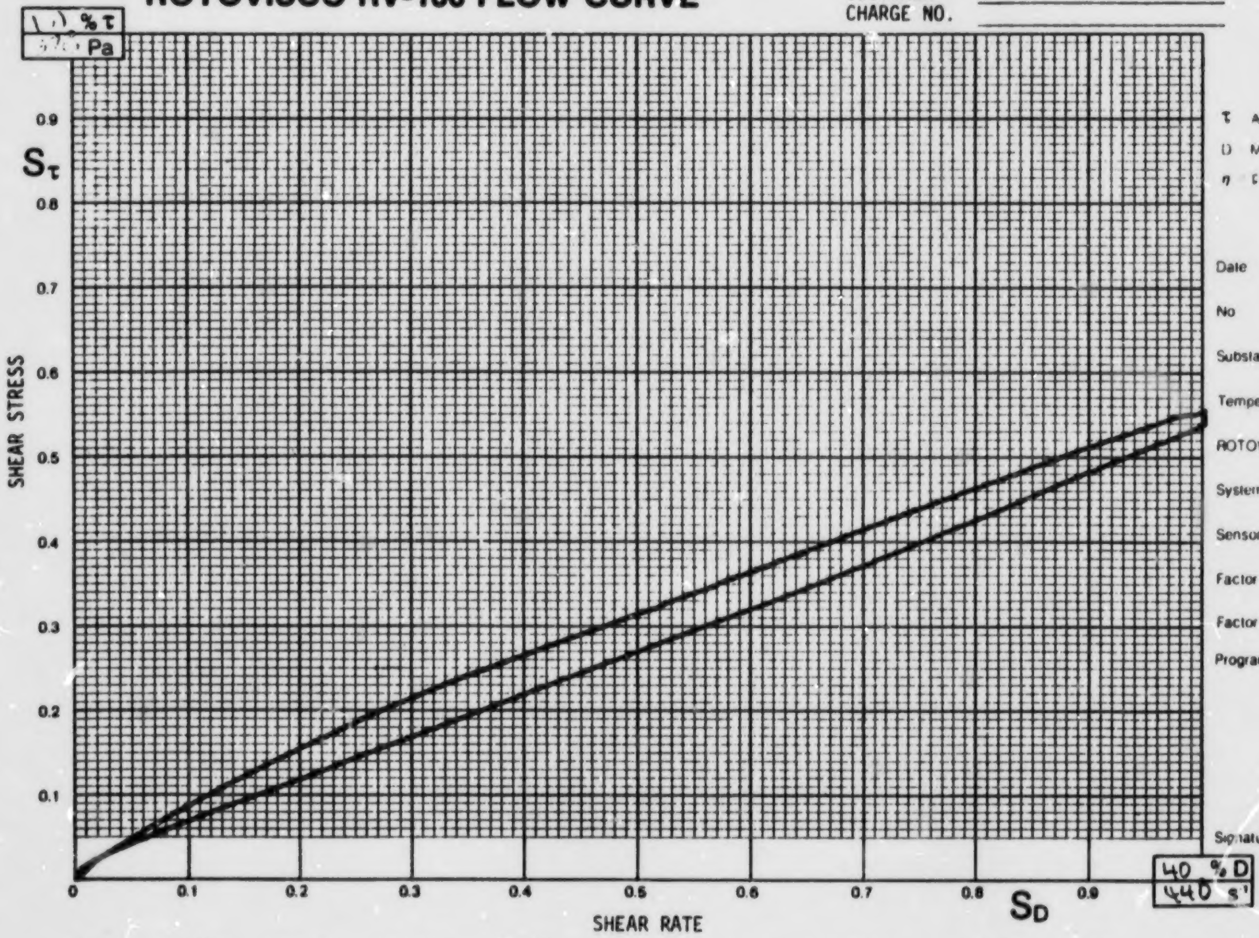


F-2541 1X1FBC 62.10 SLURRY

SHEAR RATE (1/SEC)	ASCENDING VISCOSITY (CENTIPOISE)	DESCENDING VISCOSITY (CENTIPOISE)	SHEAR RATE (1/SEC)
17.6	1901.4	1363.0	176.0
35.2	1709.1	1353.0	158.4
52.8	1623.6	1343.2	140.8
70.4	1548.9	1339.8	123.2
88.0	1499.7	1335.2	105.6
105.6	1463.4	1341.6	88.0
123.2	1440.5	1351.2	70.4
140.8	1420.7	1388.6	52.8
158.4	1407.6	1442.0	35.2
176.0	1390.8	1666.4	17.6

SAMPLE NO. F-2542
SAMPLE TYPE Composite of cws
% SOLIDS
CUSTOMER
CHARGE NO.

ROTOVISCO RV-100 FLOW CURVE

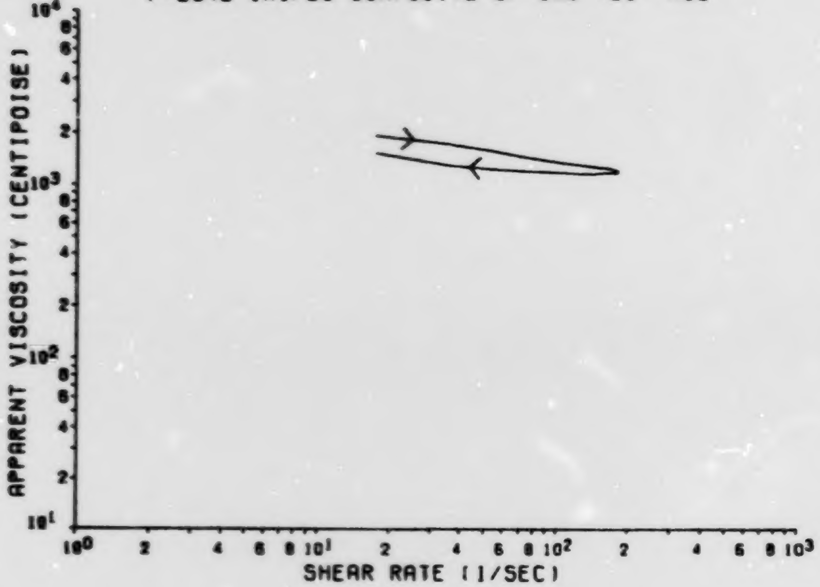


$\tau = A \cdot \%\tau \cdot S_\tau$ [Pa]
$D = M \cdot \%D \cdot S_D$ [s^{-1}]
$\eta = \tau / D$ [Pa·s]

Date 9-20-83
No
Substance Cws
Temperature 74°F
ROTOVISCO RV 100
System
Sensor system MV IIP
Factor A 3.76
Factor M 4.40
Program times
T_1 0.1
T_2 4.0
T_3 1.0
Signature

A =	0.088	0.156	0.215	0.265	0.314	0.364	0.414	0.463	0.511	0.552
D =	0.070	0.119	0.169	0.219	0.270	0.320	0.372	0.426	0.482	0.538

F-2542 1X1FBC COMPOSITE OF CWS TEST #62



F-2542 1X1FBC COMPOSITE OF CWS TEST #62

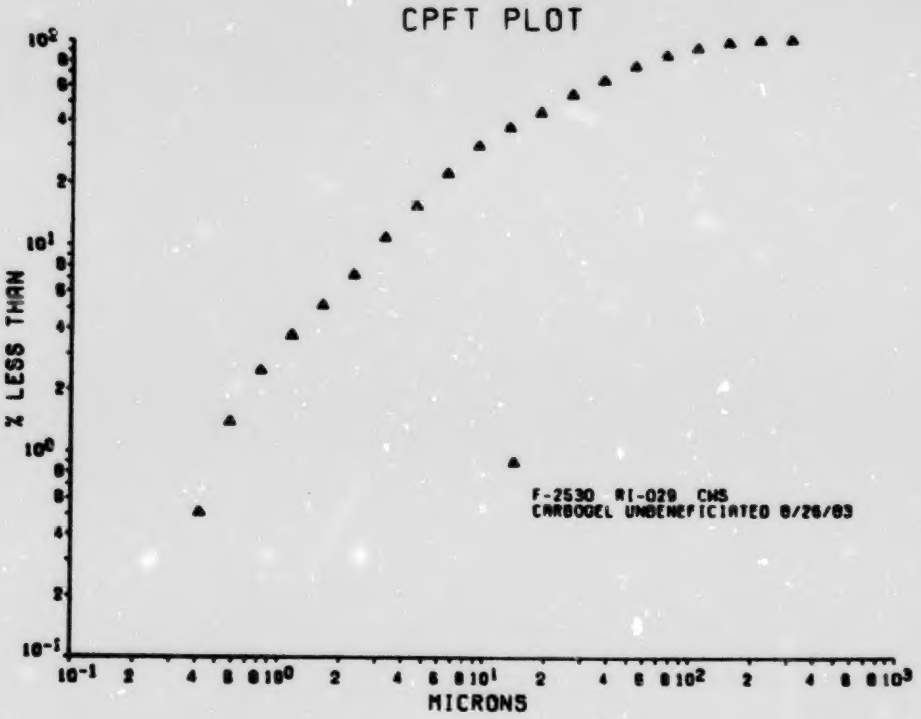
SHEAR RATE (1/SEC)	ASCENDING VISCOSITY (CENTIPOISE)	DESCENDING VISCOSITY (CENTIPOISE)	SHEAR RATE (1/SEC)
17.6	1880.0	1149.4	176.0
35.2	1666.4	1144.1	158.4
52.8	1531.1	1137.6	140.8
70.4	1415.3	1135.3	123.2
88.0	1341.6	1139.4	105.6
105.6	1296.1	1153.6	88.0
123.2	1263.5	1169.7	70.4
140.8	1236.4	1203.5	52.8
158.4	1213.0	1271.1	35.2
176.0	1179.3	1495.5	17.6

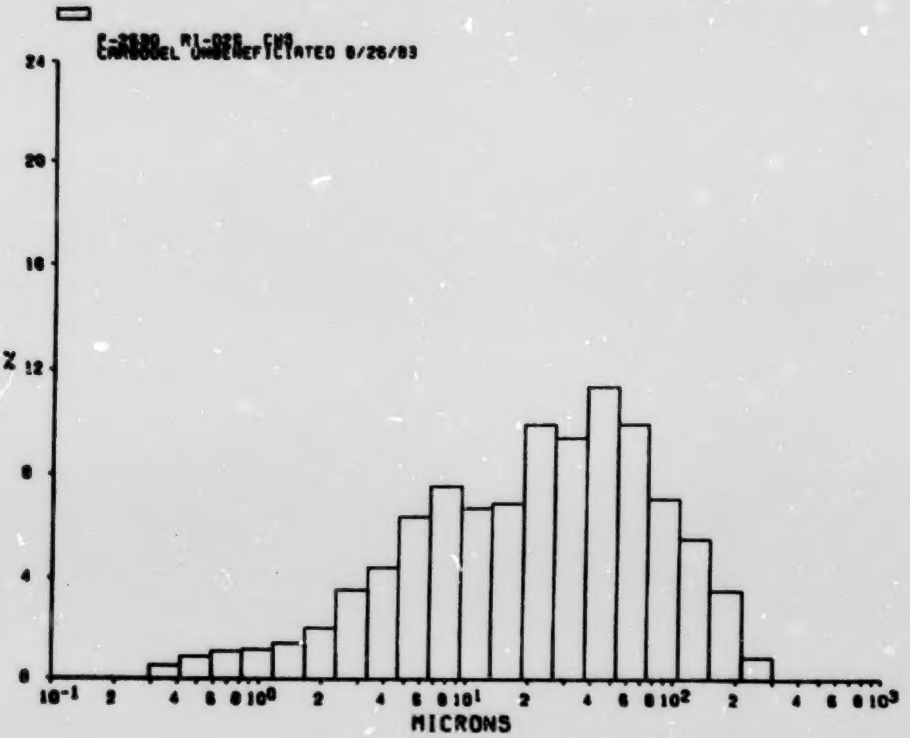
TEST SERIES 63 -- SCOTIA-LIQUICOAL UNBENEFICIATED CWS

Sample No.	F-2530	
Description	Carbogel Unbeneficiated CWS 8/26/83 (Scotia - Liquicoal)	
Basis	As Received	Dry
Total Moisture, %	39.5	--
Proximate Analysis, %		
Moisture	39.5	--
Volatile Matter	21.4	35.3
Fixed Carbon	30.8	50.9
Ash	8.3	13.8
Gross Heating Value		
Btu per Lb	7210	11920
Btu per Lb. (M&A Free)	--	13830
Ultimate Analysis, %		
Moisture	39.5	--
Carbon	40.4	66.8
Hydrogen	2.62	4.3
Nitrogen	0.71	1.17
Sulfur	3.46	5.7
Ash	8.3	13.8
Oxygen (Difference)	5.01	8.23
Total	100.00	100.00

August 31, 1983

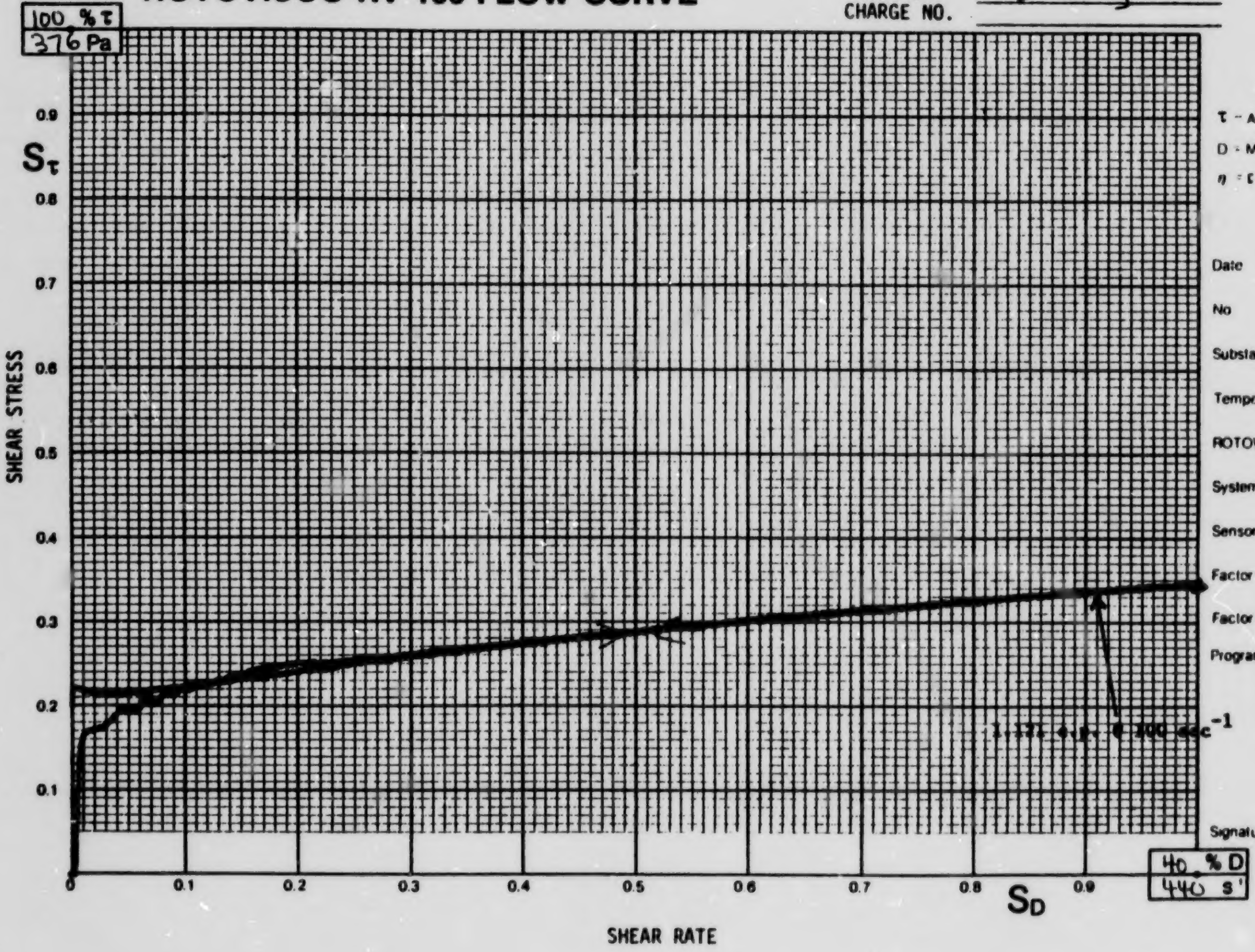
```
              F-2530  RI-029  CWS
              CARBOGEL UNBENEFICIATED 8/26/83

MICRONS       % LESS       DIFF

300.00        100.00        0.86
212.13         99.16        3.53
150.00         95.62        5.52
106.07         90.10        7.06
 75.00         83.04        9.89

 53.03         73.15       11.28
 37.50         61.87        9.38
 26.52         52.49        9.88
 18.75         42.61        6.89
 13.26         35.72        6.73

  9.38         28.98        7.54
  6.63         21.44        6.39
  4.69         15.06        4.43
  3.31         10.63        3.55
  2.34          7.08        2.02

  1.66          5.06        1.41
  1.17          3.65        1.18
  0.83          2.47        1.08
  0.59          1.39        0.88
  0.41          0.51        0.51

  0.29          0.00        0.00
  0.21
  0.15

              CS(CAL SURF AREA)= [illegible] M**2/CM**3
              MMD(D43)=41.90 MI[illegible]
              SMD(D32)=6.83 MICR[illegible]
```


CPFT PLOT
% LESS THAN
10²
8
6
4
2
10¹
8
6
4
2
10⁰
8
6
4
2
10⁻¹
10⁻¹ 2 4 6 8 10⁰ 2 4 6 8 10¹ 2 4 6 8 10² 2 4 6 8 10³
MICRONS
F-2530 RI-029 CHS
CARBOGEL UNBENEFICIATED 8/26/83


F-2530 RI-029 CHS
CARBOGEL UNBENEFICIATED 8/26/83
%
24
20
16
12
8
4
0
10⁻¹ 2 4 6 8 10⁰ 2 4 6 8 10¹ 2 4 6 8 10² 2 4 6 8 10³
MICRONS

ROTOVISCO RV-100 FLOW CURVE

SAMPLE NO. F-2530
SAMPLE TYPE CWS
% SOLIDS
CUSTOMER D. Rowley
CHARGE NO.

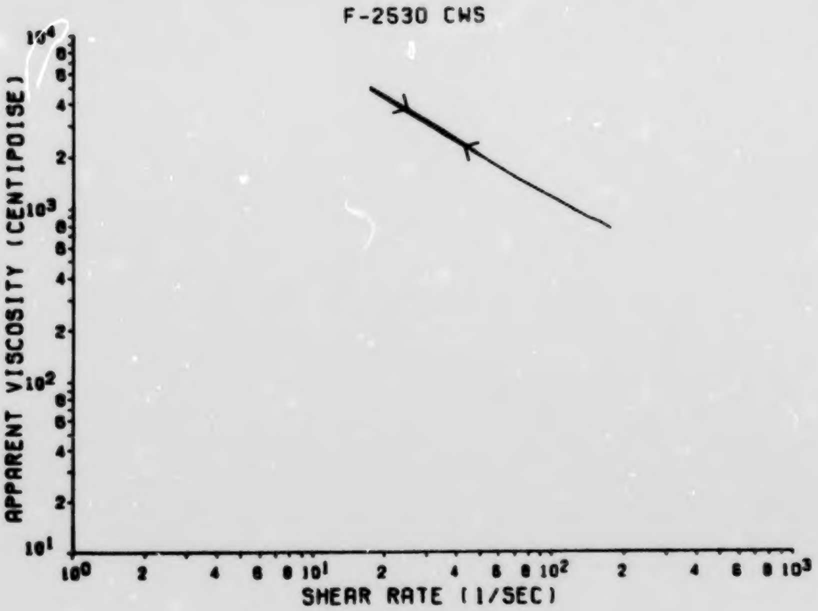


$\tau = A \cdot \%\tau \cdot S_\tau$ [Pa]
$D = M \cdot \%D \cdot S_D$ [s^{-1}]
$\eta = \tau / D$ [Pa·s]

Date 8-30-83
No
Substance CWS
Temperature 76 °F
ROTOVISCO RV 100
System
Sensor system [illegible]
Factor A [illegible]
Factor M 1.40
Program times
T_1 0.1
T_2 4.0
T_3 1.0
Signature [illegible]

F-2530 CWS

SHEAR RATE (1/SEC)	ASCENDING VISCOSITY (CENTIPOISE)	DESCENDING VISCOSITY (CENTIPOISE)	SHEAR RATE (1/SEC)
17.6	4764.1	737.0	176.0
35.2	2681.1	802.3	158.4
52.8	1844.4	862.6	140.8
70.4	1458.1	952.2	123.2
88.0	1234.8	1071.7	105.6
105.6	1071.7	1234.8	88.0
123.2	952.2	1458.1	70.4
140.8	862.6	1844.4	52.8
158.4	802.3	2563.6	35.2
176.0	737.0	4678.6	17.6



1 X 1 FBC

COMBUSTION TECHNOLOGY
ACG-84-4096-03
October 25, 1983

Sample No.	F-2615 Coal-Water Slurry Composite for Test Series 63	
Basis	As Received	Dry
Total Moisture, %	41.00	--
Solids	59.00	--
Proximate Analysis, %		
Moisture	41.00	--
Volatile Matter	21.65	36.7
Fixed Carbon	28.62	48.5
Ash	8.73	14.8
Gross Heating Value Btu per Lb.	6970	11810
Btu per Lb. (M&A Free)	--	13860
Ultimate Analysis, %		
Moisture	41.00	--
Carbon	39.88	67.6
Hydrogen	2.51	4.3
Nitrogen	0.62	1.05
Sulfur	3.44	5.83
Ash	8.73	14.8
Oxygen (Difference)	3.82	6.42
Total	100.00	100.00

Ash (% by ICP)

SiO_2	29.41
Al_2O_3	13.04
Fe_2O_3	30.66
TiO_2	0.45
CaO	6.46
MgO	1.52
Na_2O*	2.16
K_2O*	2.05
SO_3	10.37
P_2O_5	0.33
Total	96.45

*By flame

1 X 1 FBC

Sample No.	M-38387
Description	Limestone Composite For Test Series 63
Moisture, %	0.10
Calcium as CaO, (Dry), %	50.4
Magnesium as MgO, (Dry), %	0.48
Carbonate as Co_2, (Dry), %	40.7

SCREENINGS

REFERENCE NO. B&W 103 T-74 ASTM-D-197-30 ASTM-D-311

BALANCE NO: 581937 **JOB:** 1x1

ROTAP NO: 3944 **DATE:** 10-6-83

Limestone

SAMPLE NO: M-38387 **SAMPLE MOISTURE:** As Rec.D

WEIGHT IN GRAMS: 100.0

SCREENS	IND. WT. ON.	COMB. WT. ON	% ON	% THRU
3 INCH				
2 INCH				
1-1/2 INCH				
1 INCH				
3/4 INCH				
1/2 INCH				
1/4 INCH	0	0	0	100.0
4 MESH	.80	.80	.8	99.2
8 MESH	4.14	4.94	4.9	95.1
16 MESH	38.04	42.98	43.0	57.0
30 MESH	20.57	63.55	63.6	36.4
50 MESH	12.71	76.26	76.3	23.7
70 MESH				
100 MESH	8.16	84.42	84.4	15.6
140 MESH				
200 MESH	5.38	89.80	89.8	10.2
270 MESH				
325 MESH	3.13	92.93	92.9	7.1

PAN: 6.61
.25
6.86

1 X 1 FBC

Sample No.	F-2606		F-2607		F-2608	
Description	CWS 1330	63.1 9-9-83	CWS 1005	63.2 9-12-83	CWS 1405	63.3 9-12-83
Basis	As Received	Dry	As Received	Dry	As Received	Dry
Moisture, %	41.0	--	41.1	--	40.3	--
Solids	59.0	100.0	58.9	100.0	59.7	100.0
Carbon, %	40.06	67.9	39.47	67.0	39.94	66.9
Sulfur as S, %	3.42	5.80	3.53	5.99	3.37	5.64

Sample No.	F-2609		F-2610		F-2611	
Description	CWS 1043	63.4 9-13-83	CWS 0800	63.5 9-14-83	CWS 1125	63.6 9-14-83
Basis	As Received	Dry	As Received	Dry	As Received	Dry
Moisture, %	40.1	--	38.9	--	40.2	--
Solids	59.9	100.0	61.1	100.0	59.8	100.0
Carbon, %	39.62	66.1	40.74	66.7	39.82	66.6
Sulfur as S, %	3.38	5.64	3.39	5.55	3.30	5.52

Sample No.	F-2612		F-2613		F-2614	
Description	CWS 1420	63.7 9-14-83	CWS 1235	63.8 9-15-83	CWS 1500	63.9 9-15-83
Basis	As Received	Dry	As Received	Dry	As Received	Dry
Moisture, %	39.5	--	39.5	--	39.3	--
Solids	60.5	100.0	60.5	100.0	60.7	100.0
Carbon, %	40.00	66.1	39.58	65.4	39.81	65.6
Sulfur as S, %	3.47	5.74	3.69	6.10	3.40	5.60

1 X 1 FBC

ACG-84-4096-03
October 25, 1983

Sample No.	M-38378	M-38379	M-38380	M-38381
Description	Bed Ash 63.1 1339 9-9-83	Bed Ash 63.2 1140 9-12-83	Bed Ash 63.3 1513 9-12-83	Bed Ash 63.4 1020 9-13-83
Moisture, %	None	None	None	None
Ash, Dry, %	99.6	99.8	99.8	99.5
Calcium as CaO, Dry, %	55.4	54.0	55.4	57.2
Sulfur as S, Dry, %	11.10	11.49	11.73	10.46
Sulfur as So_3, Dry, %	27.74	28.73	29.33	26.16
Carbonate as CO_2, Dry, %	0.33	0.19	0.17	0.35
Carbon (Ult.). Dry, % (Corr. for CO_2)	0.07	0.03	0.02	0.03
Sizing				
% Through 1/4"	100.0	100.0	100.0	100.0
# 4	98.6	99.0	99.2	99.7
8	84.6	93.8	94.4	95.4
16	50.5	65.8	51.2	57.6
30	16.9	26.7	16.0	19.2
50	0.3	1.2	0.1	0.3
100	0.2	0.1	0.0	0.0

1 X 1 FBC

ACG-84-4096-03
October 25, 1983

Sample No.	M-38382	M-38383	M-38384	M-38385	M-38386
Description	Bed Ash 63.5 0750 9-14-83	Bed Ash 63.6 1119 9-14-83	Bed Ash 63.7 1504 9-14-83	Bed Ash 63.8 1046 9-15-83	Bed Ash 63.9 1435 9-15-83
Moisture, %	None	None	None	None	None
Ash, Dry, %	99.7	99.9	99.9	99.9	99.9
Calcium as CaO, Dry, %	55.6	56.3	53.6	53.2	54.9
Sulfur as SO, Dry, %	11.49	11.31	12.63	12.10	12.06
Sulfur as SO_3, Dry, %	28.72	28.28	31.57	30.25	30.14
Carbonate as CO_2, Dry, %	0.16	0.12	0.11	0.17	0.16
Carbon (Ult.). Dry, % (Corr. for CO_2)	0.03	0.04	0.01	None	None
Sizing					
% Through 1/4"	100.0	100.0	100.0	100.0	100.0
# 4	99.7	99.5	99.8	99.3	99.7
8	92.5	94.0	95.8	96.0	95.7
16	61.2	65.9	64.1	67.5	61.2
30	22.6	27.6	22.9	30.8	24.7
50	0.7	1.0	0.3	1.2	1.3
100	0.1	0.2	0.1	0.0	0.1

1 X 1 FBC

ACG-84-4096-03
October 25, 1983

Sample No.	K-26600	K-26601	K-26602	K-26603
Description	Cyclone Ash			
	63.1	63.2	63.3	63.4
	1400	1130	1530	1030
	9-9-83	9-12-83	9-12-83	9-13-83
Moisture, %	0.7	0.3	0.2	0.9
Ash, Dry, %	74.9	84.4	81.2	79.1
Calcium as CaO, Dry, %	21.0	42.3	41.1	24.2
Sulfur as S, Dry, %	2.82	4.01	5.06	3.38
Sulfur as SO_3, Dry, %	7.06	10.03	12.65	8.46
Carbonate as CO_2, Dry, %	3.96	6.28	6.59	4.55
Carbon (Ult.). Dry, % (Corr. for CO_2)	20.5	9.0	12.4	14.8
Sizing				
% Through #16	100.0	100.0	100.0	---
30	99.9	99.9	99.8	100.0
50	97.4	99.4	83.3	99.96
100	93.8	79.2	58.1	99.7
200	87.9	57.1	45.4	97.8
325	79.0	44.5	36.0	92.4

1 X 1 FBC

ACG-84-4096-03
October 25, 1983

Sample No.	K-26604	K-26605	K-26606	K-26607	K-26608
Description	Cyclone Ash				
	63.5	63.6	63.7	63.8	63.9
	0800	1100	1500	1130	1430
	9-14-83	9-14-83	9-14-83	9-15-83	9-15-83
Moisture, %	0.6	None	0.3	0.4	0.3
Ash, Dry, %	75.0	91.2	79.5	81.4	79.7
Calcium as CaO, Dry, %	30.3	51.2	30.3	33.7	41.5
Sulfur as S, Dry, %	3.38	6.24	4.98	4.73	4.60
Sulfur as SO_3, Dry, %	8.45	15.61	12.44	11.82	11.50
Carbonate as CO_2, Dry, %	4.32	3.90	3.26	3.80	5.60
Carbon (Ult.). Dry, % (Corr. for CO_2)	19.8	5.2	16.5	13.8	14.7
Sizing					
% Through #16	100.0	100.0	100.0	100.0	100.0
30	99.9	99.9	99.8	99.9	99.9
50	96.2	92.9	88.8	99.5	99.5
100	84.7	54.4	67.1	93.9	83.6
200	66.5	36.0	53.1	80.3	57.8
325	45.7	24.3	40.5	63.7	36.5

1 X 1 FBC

ACG-84-4096-03
October 25, 1983

Sample No.	K-26609	K-26610	K-26611	K-26612
Description	Baghouse Ash			
	63.1 1410 9-9-83	63.2 1145 9-12-83	63.3 1530 9-12-83	63.4 1038 9-13-83
Moisture, %	0.4	2.4	0.5	1.2
Ash, Dry, %	87.1	88.2	88.9	88.4
Calcium as CaO, Dry, %	21.0	21.2	21.8	23.5
Sulfur as S, Dry, %	4.30	4.33	4.78	5.78
Sulfur as SO_3, Dry, %	10.74	10.82	11.96	14.45
Carbonate as CO_2, Dry, %	1.42	1.45	1.64	2.45
Carbon (Ult.). Dry, % (Corr. for CO_2)	10.5	8.0	8.2	7.2

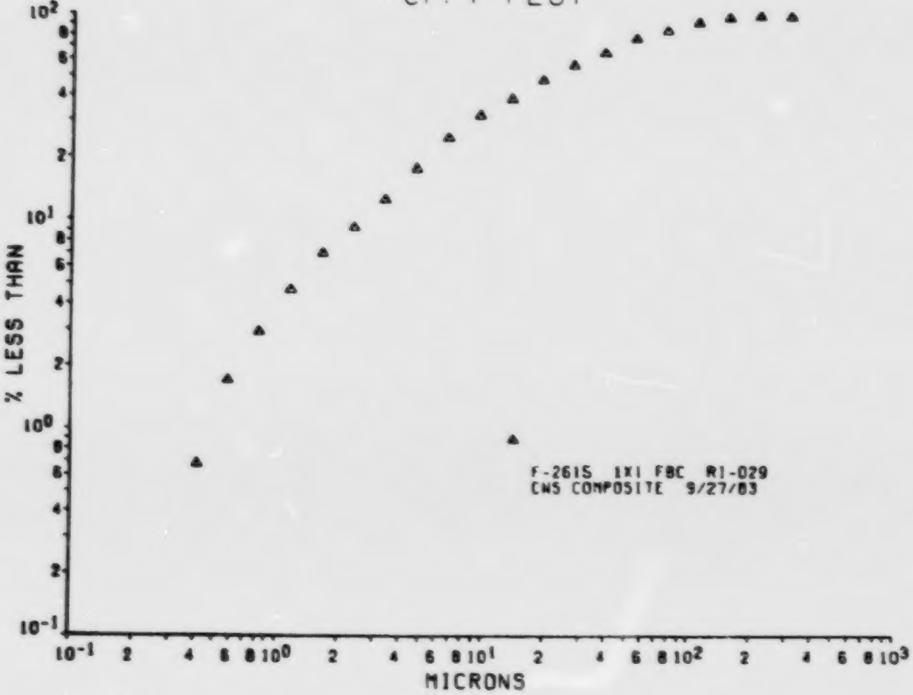
1 X 1 FBC

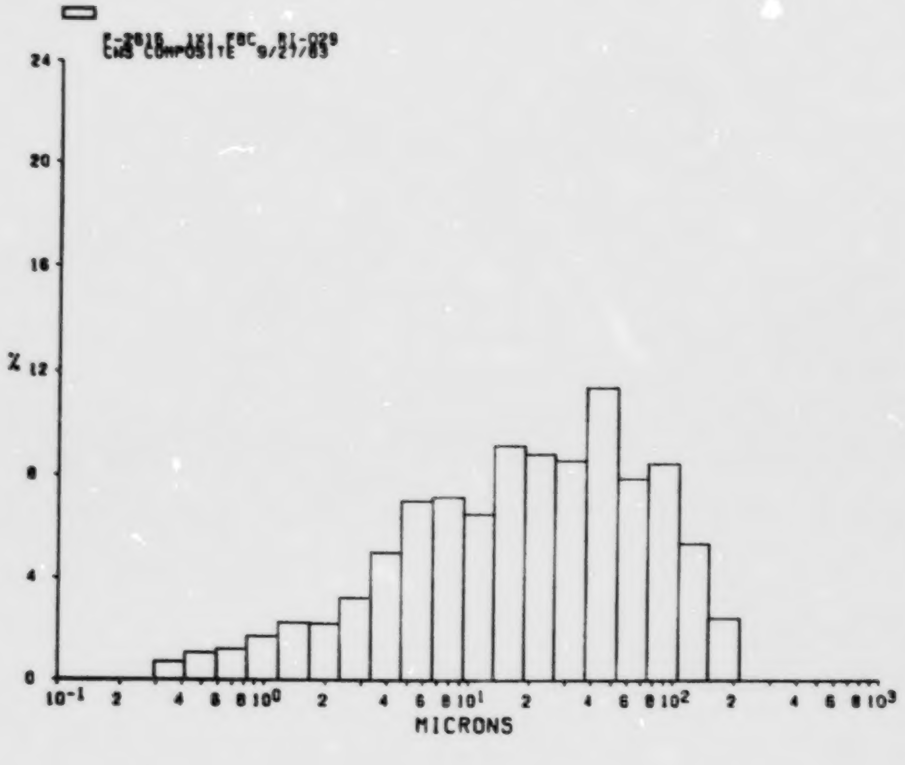
ACG-84-4096-03
October 25, 1983

Sample No.	K-26613	K-26614	K-26615	K-26616	K-26617
Description	Baghouse Ash				
	63.5 0810 9-14-83	63.6 1145 9-14-83	63.7 1505 9-14-83	63.8 1130 9-15-83	63.9 1505 9-15-83
Moisture, %	1.8	8.2	2.6	2.0	0.8
Ash, Dry, %	88.1	86.2	88.1	88.6	89.8
Calcium as CaO, Dry, %	22.0	21.7	19.9	18.6	18.5
Sulfur as S, Dry, %	4.90	4.96	4.49	5.05	4.38
Sulfur as SO_3, Dry, %	12.24	12.39	11.22	12.63	10.96
Carbonate as CO_2, Dry, %	1.85	3.15	1.70	1.33	0.91
Carbon (Ult.). Dry, % (Corr. for CO_2)	8.2	8.3	8.3	8.2	8.1

```
% + 300 microns = 0.07

F-2615  IXI FBC  RI-029
CWS COMPOSITE  9/27/83

MICRONS   % LESS    DIFF

300.00
212.13    100.00     2.42
160.00     97.58     5.38
106.07     92.20     8.47
 75.00     83.73     7.89

 53.03     75.85    11.36
 37.60     64.49     8.55
 26.52     55.93     8.82
 18.76     47.11     9.15
 13.26     37.96     6.50

  9.38     31.47     7.14
  6.63     24.33     7.01
  4.69     17.32     5.00
  3.31     12.32     3.22
  2.34      9.10     2.23

  1.66      6.88     2.25
  1.17      4.63     1.71
  0.83      2.92     1.21
  0.59      1.72     1.04
  0.41      0.68     0.68

  0.29      0.00     0.00
  0.21
  0.15

          CS(CAL SURF AREA)=1.02 M**2/CM**3
          MMD(D43)=37.43 MICRONS
          SMD(D32)=5.90 MICRONS
```

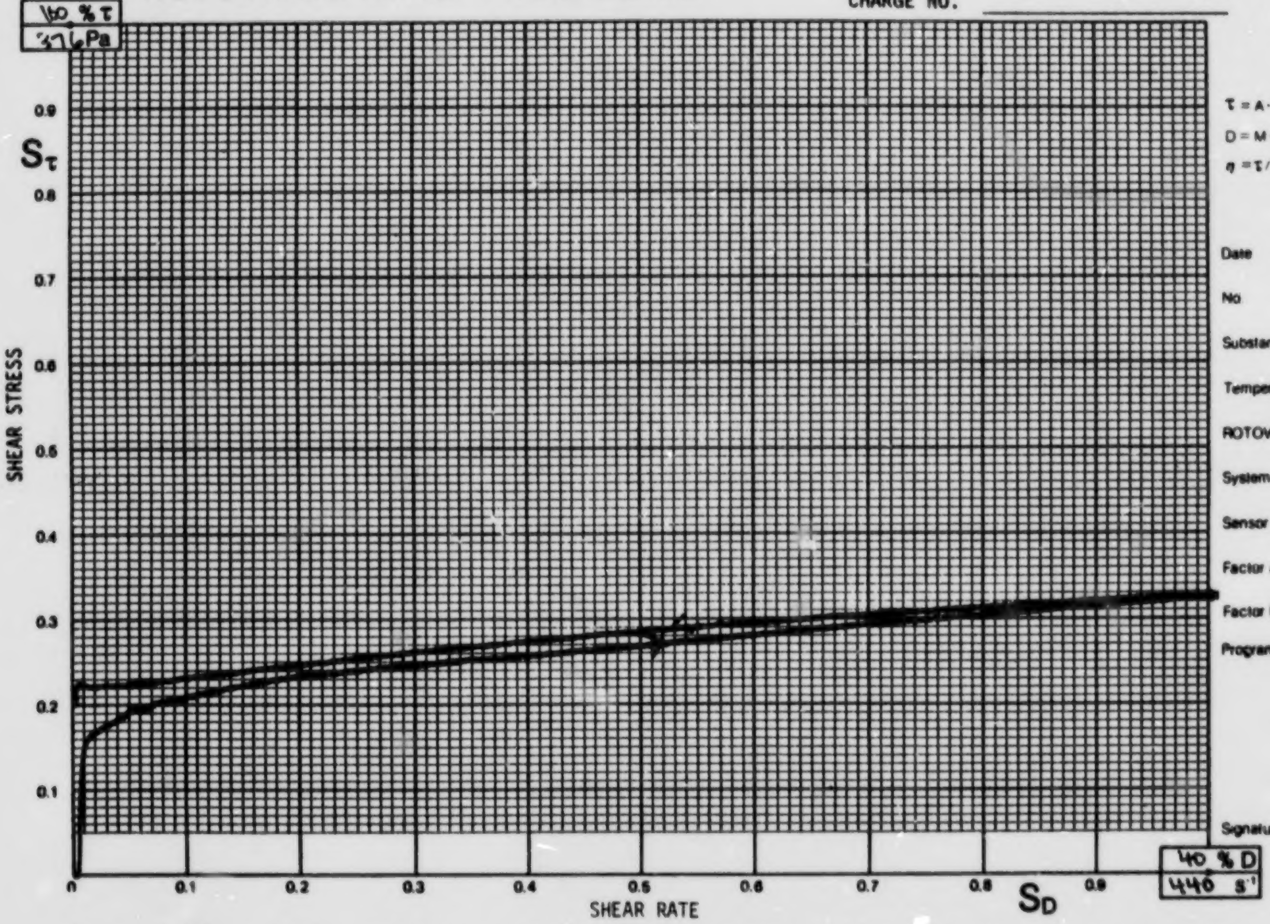
CPFT PLOT




F-2816 1X1 FBC 81-029
CWS COMPOSITE 9/27/83
24
20
16
%
12
8
4
0
10^{-1}
2
4
6
8
10^{0}
2
4
6
8
10^{1}
2
4
6
8
10^{2}
2
4
6
8
10^{3}
MICRONS

SAMPLE NO. F-2606
SAMPLE TYPE CWS 63.1
% SOLIDS
CUSTOMER
CHARGE NO.

ROTOVISCO RV-100 FLOW CURVE



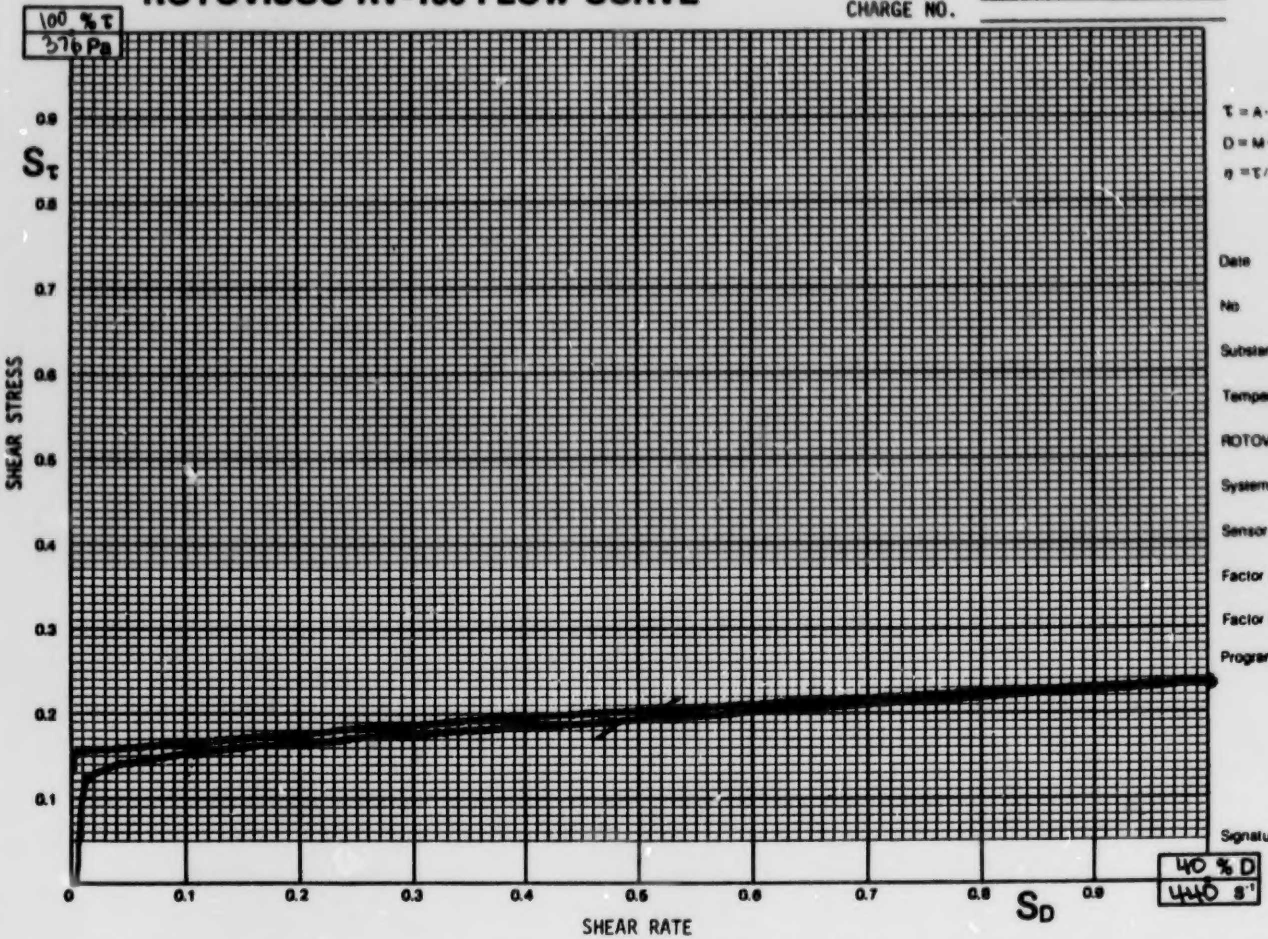
A =	0.208	0.233	0.246	0.258	0.269	0.280	0.292	0.302	0.315	0.325
D =	0.231	0.248	0.261	0.273	0.284	0.295	0.303	0.311	0.320	0.326

$\tau = A \cdot \%\tau \cdot S_\tau$ [Pa]
$D = M \cdot \%D \cdot S_D$ [s^{-1}]
$\eta = \tau / D$ [Pa·s]

Date [illegible]
No
Substance CWS
Temperature [illegible]
ROTOVISCO RV 100
System
Sensor system [illegible]
Factor A [illegible]
Factor M [illegible]
Program times
T_1 [illegible]
T_2 [illegible]
T_3 [illegible]
Signature [illegible]

ROTOVISCO RV-100 FLOW CURVE

SAMPLE NO. F-2607
SAMPLE TYPE CWS 63.2
% SOLIDS
CUSTOMER
CHARGE NO.



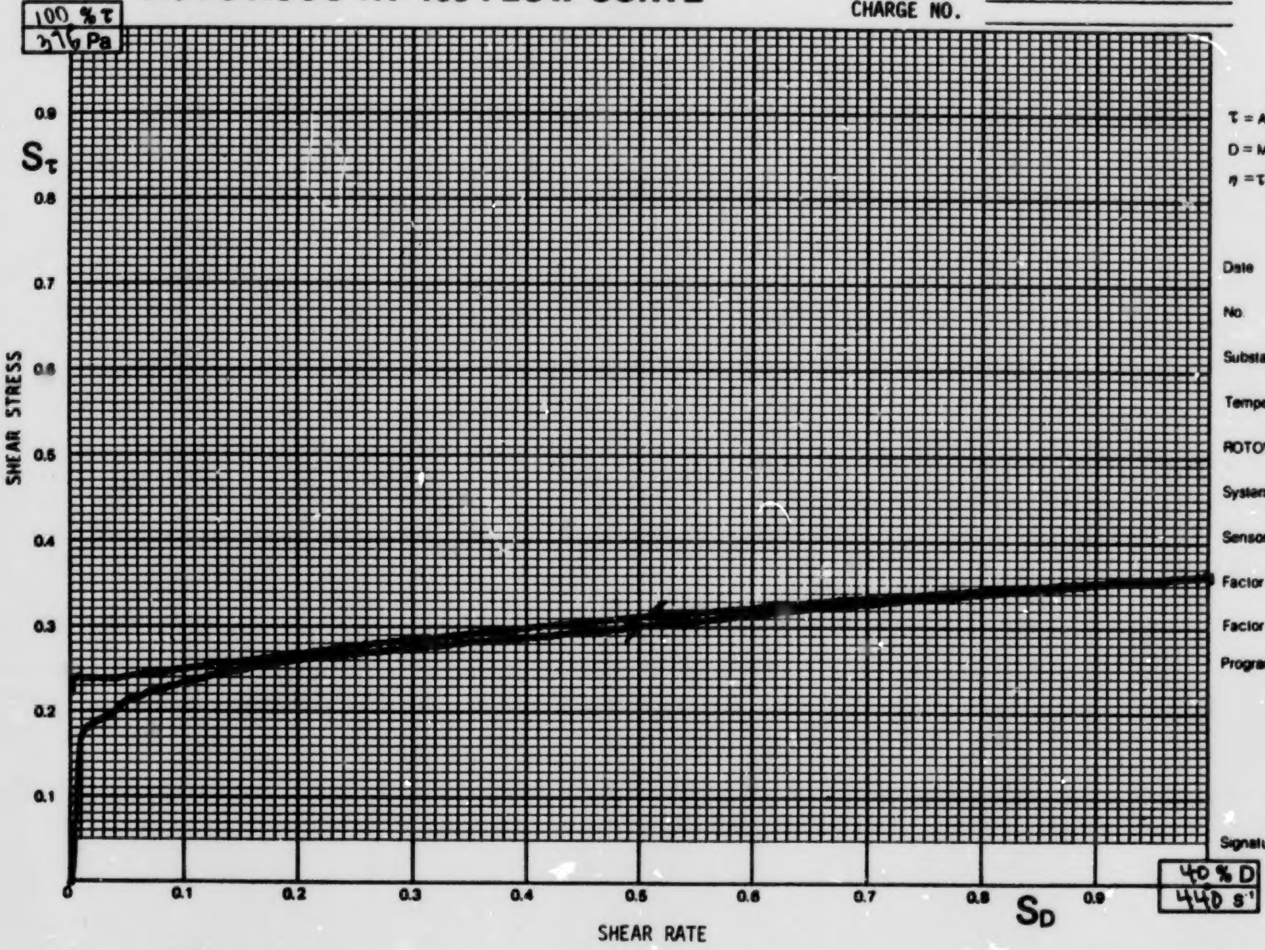
$\tau = A \cdot \%\tau \cdot S_\tau$ [Pa]
$D = M \cdot \%D \cdot S_D$ [s^{-1}]
$\eta = \tau / D$ [Pa·s]

Date [illegible]
No [illegible]
Substance [illegible]
Temperature [illegible]
ROTOVISCO RV [illegible]
System [illegible]
Sensor system [illegible]
Factor A [illegible]
Factor M [illegible]
Program times
T_1 [illegible]
T_2 [illegible]
T_3 [illegible]
Signature [illegible]

A =	0.152	0.166	0.177	0.183	0.191	0.201	0.210	0.219	0.228	0.231
D =	0.165	0.178	0.189	0.197	0.203	0.210	0.219	0.224	0.230	0.232

SAMPLE NO. F-2608
SAMPLE TYPE CWS 63.3
% SOLIDS
CUSTOMER
CHARGE NO.

ROTOVISCO RV-100 FLOW CURVE



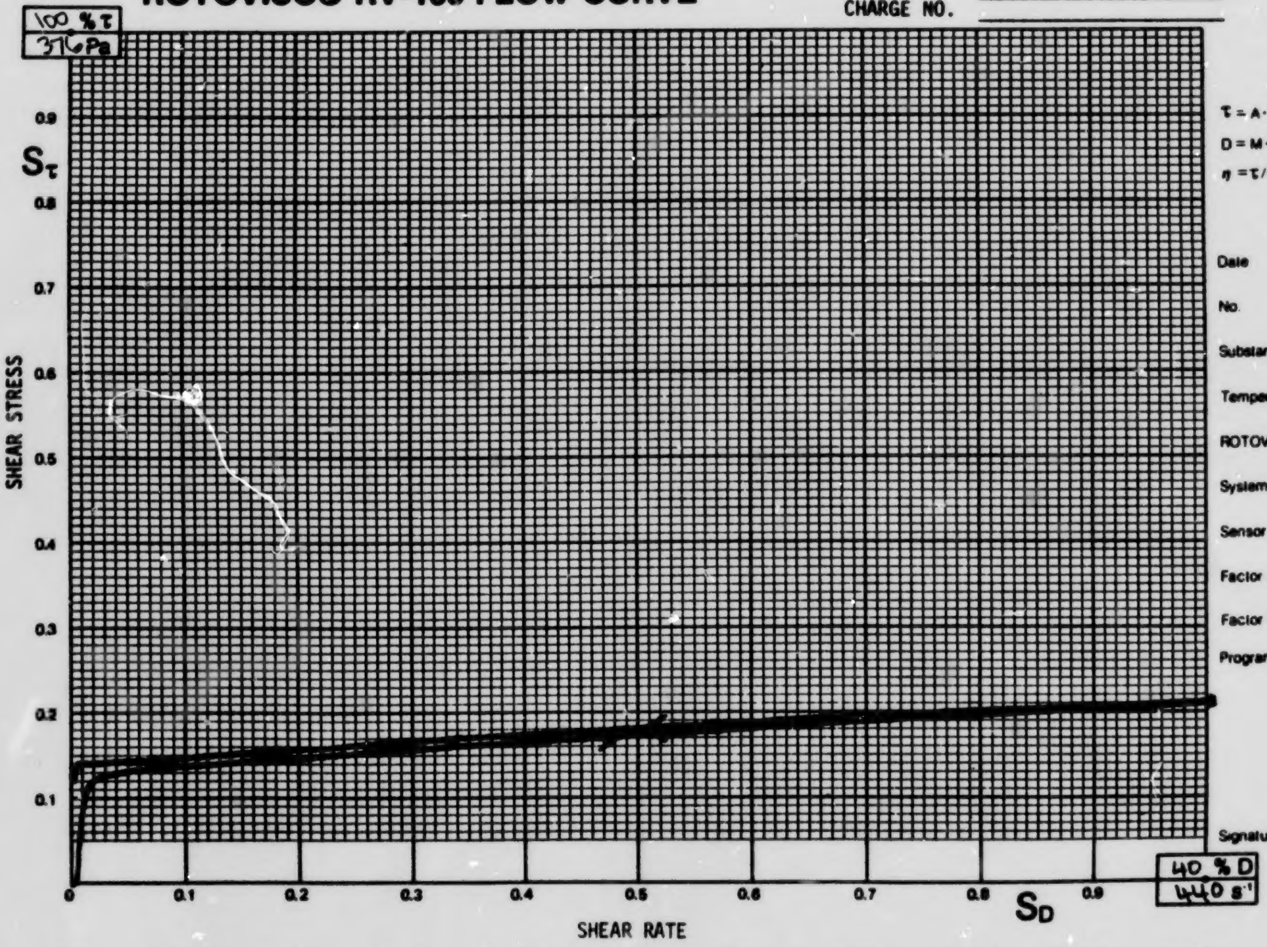
A =	0.232	0.260	0.275	0.289	0.300	0.312	0.329	0.341	0.351	0.360
D =	0.250	0.269	0.285	0.300	0.311	0.321	0.334	0.344	0.352	0.360

$\tau = A \cdot \%\tau \cdot S_\tau$ [Pa]
$D = M \cdot \%D \cdot S_D$ [s^{-1}]
$\eta = \tau / D$ [Pa·s]

Date [redacted]
No. [redacted]
Substance [redacted]
Temperature [redacted]
ROTOVISCO RV [redacted]
System [redacted]
Sensor system [redacted]
Factor A [redacted]
Factor M [redacted]
Program times
T_1 [redacted]
T_2 [redacted]
T_3 [redacted]
Signature [redacted]

SAMPLE NO. F-2609
SAMPLE TYPE CWS 63.4
% SOLIDS
CUSTOMER
CHARGE NO.

ROTOVISCO RV-100 FLOW CURVE



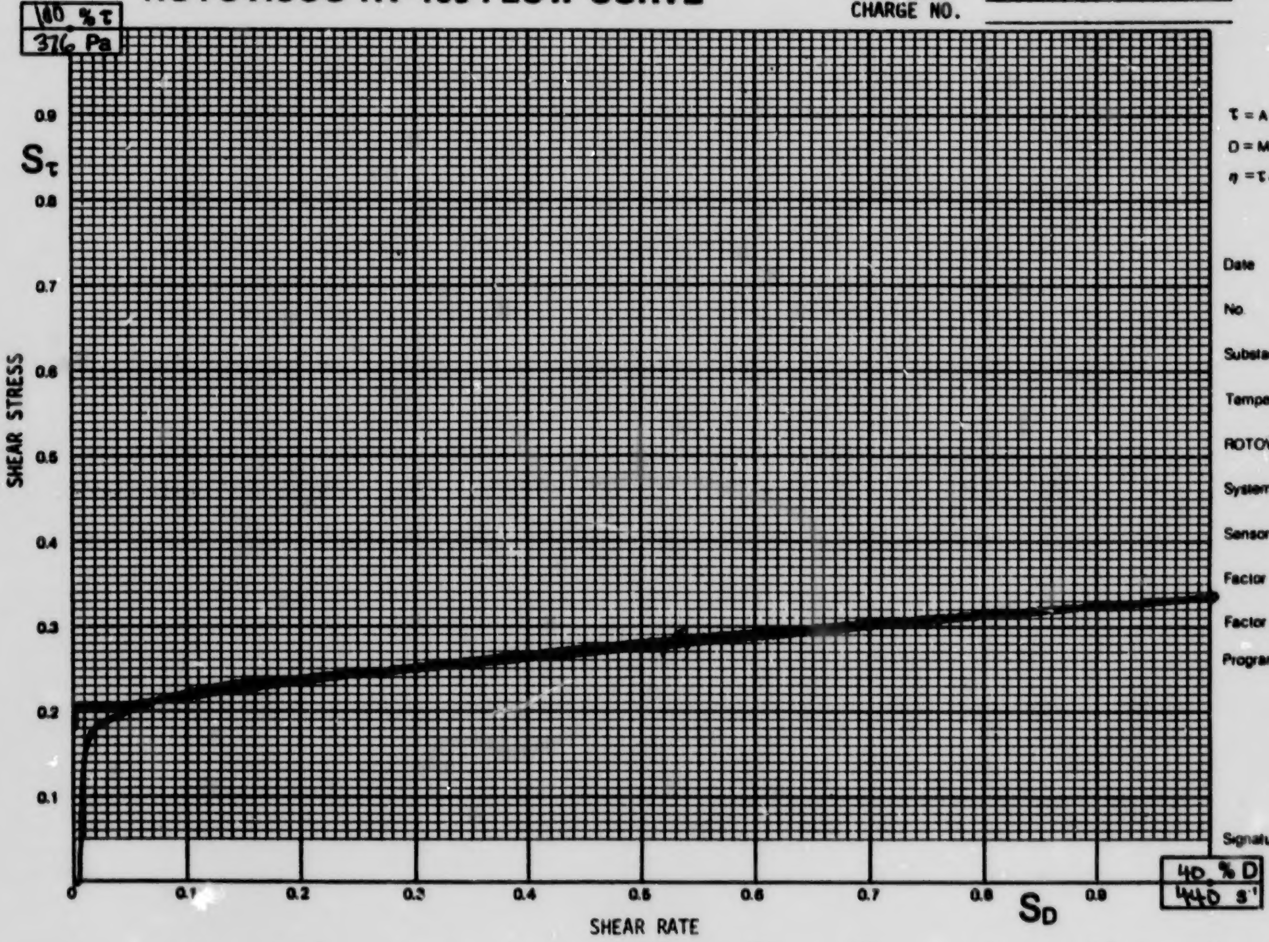
A =	0.139	0.148	0.158	0.163	0.171	0.180	0.190	0.196	0.202	0.210
D =	0.149	0.158	0.168	0.173	0.181	0.189	0.196	0.200	0.206	0.210

$\tau = A \cdot \%\tau \cdot S_\tau$ [Pa]
$D = M \cdot \%D \cdot S_D$ [s^{-1}]
$\eta = \tau / D$ [Pa·s]

Date [illegible]
No. [illegible]
Substance [illegible]
Temperature [illegible]
ROTOVISCO RV [illegible]
System [illegible]
Sensor system [illegible]
Factor A [illegible]
Factor M [illegible]
Program times
T_1 [illegible]
T_2 [illegible]
T_3 [illegible]
Signature [illegible]

SAMPLE NO. F-2610
SAMPLE TYPE CWS 63.5
% SOLIDS
CUSTOMER
CHARGE NO.

ROTOVISCO RV-100 FLOW CURVE



$\tau = A \cdot \%\tau \cdot S_\tau\ [Pa]$

$D = M \cdot \%D \cdot S_D\ [s^{-1}]$

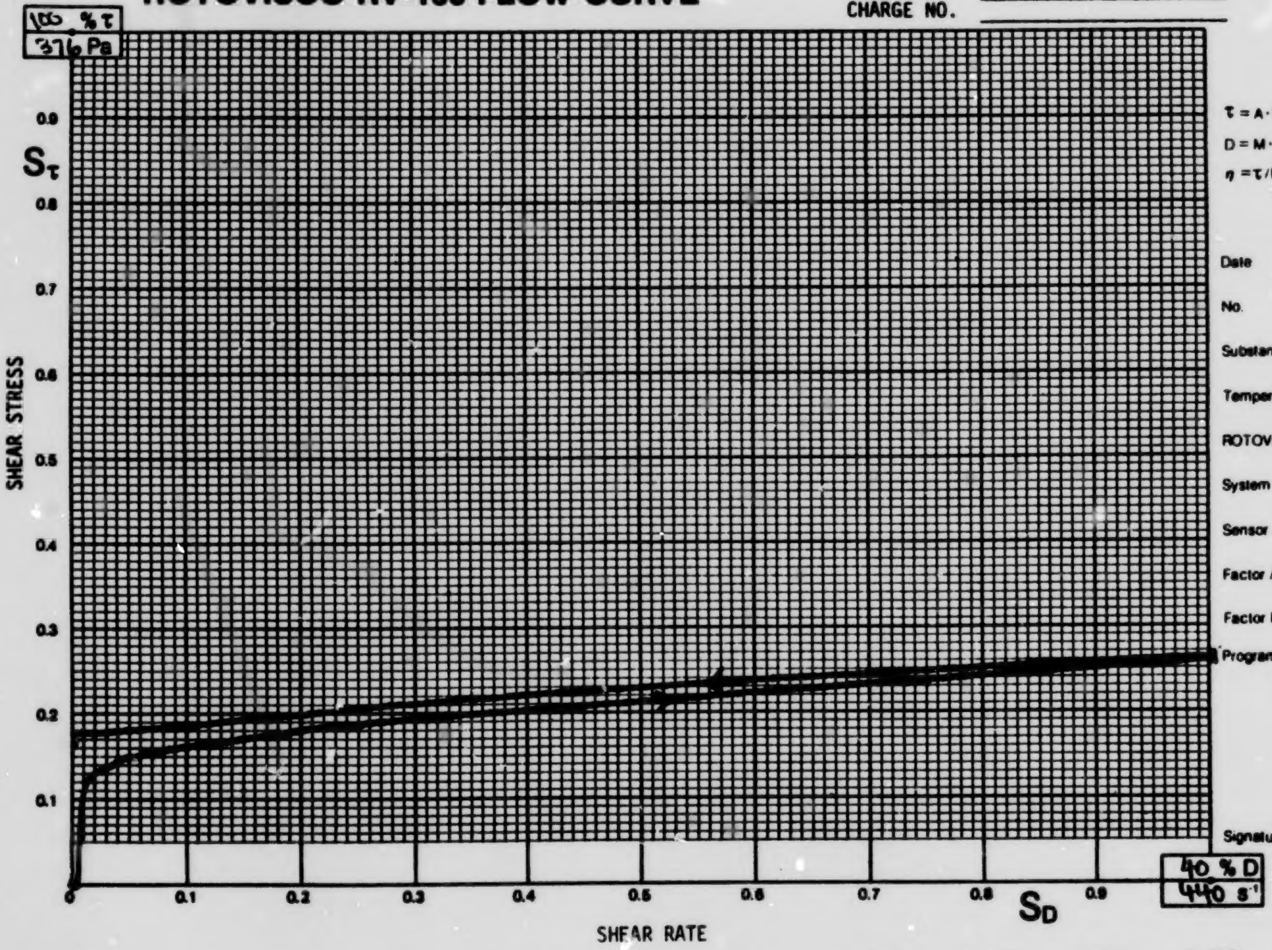
$\eta = \tau / D\ [Pa \cdot s]$

Date [redacted]
No. [redacted]
Substance [redacted]
Temperature [redacted]
ROTOVISCO RV [redacted]
System [redacted]
Sensor system [redacted]
Factor A [redacted]
Factor M [redacted]
Program times
T_1 [redacted]
T_2 [redacted]
T_3 [redacted]
Signature [redacted]

A =	0.222	0.238	0.250	0.262	0.273	0.288	0.301	0.311	0.321	0.331
D =	0.218	0.236	0.252	0.268	0.281	0.293	0.303	0.312	0.322	0.331

SAMPLE NO. F-2611
SAMPLE TYPE OWS 63.6
% SOLIDS
CUSTOMER
CHARGE NO.

ROTOVISCO RV-100 FLOW CURVE



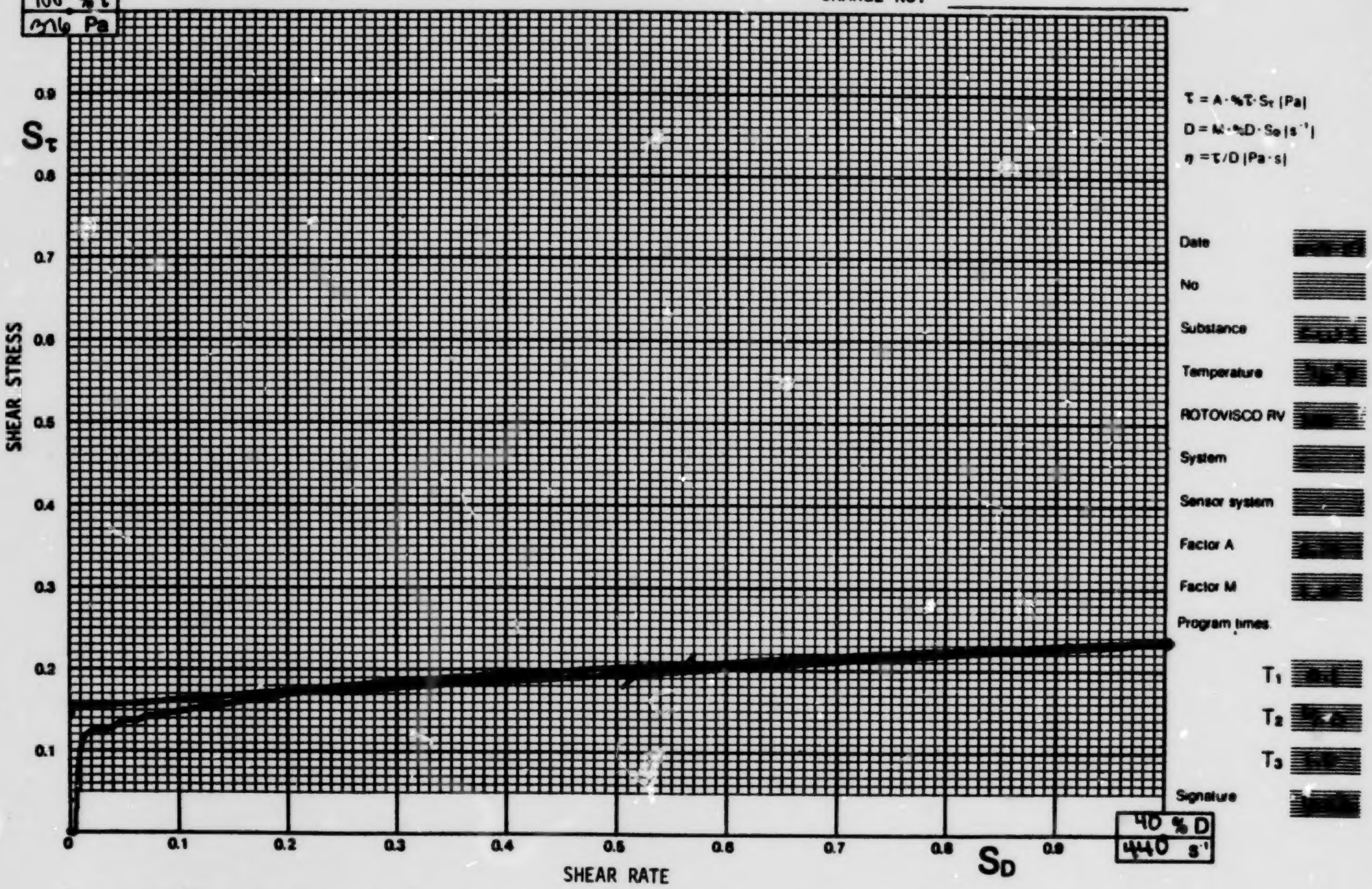
$\tau = A \cdot \%\tau \cdot S_\tau$ [Pa]
$D = M \cdot \%D \cdot S_D$ [s^{-1}]
$\eta = \tau / D$ [Pa·s]

Date [illegible]
No. [illegible]
Substance [illegible]
Temperature [illegible]
ROTOVISCO RV [illegible]
System [illegible]
Sensor system [illegible]
Factor A [illegible]
Factor M [illegible]
Program times
T_1 0.1
T_2 [illegible]
T_3 1.0
Signature [illegible]

A =	0.161	0.180	0.192	0.202	0.211	0.222	0.232	0.241	0.250	0.260
D =	0.186	0.199	0.210	0.221	0.230	0.238	0.245	0.251	0.259	0.260

SAMPLE NO. F-2612
SAMPLE TYPE Cws 63.7
% SOLIDS
CUSTOMER
CHARGE NO.

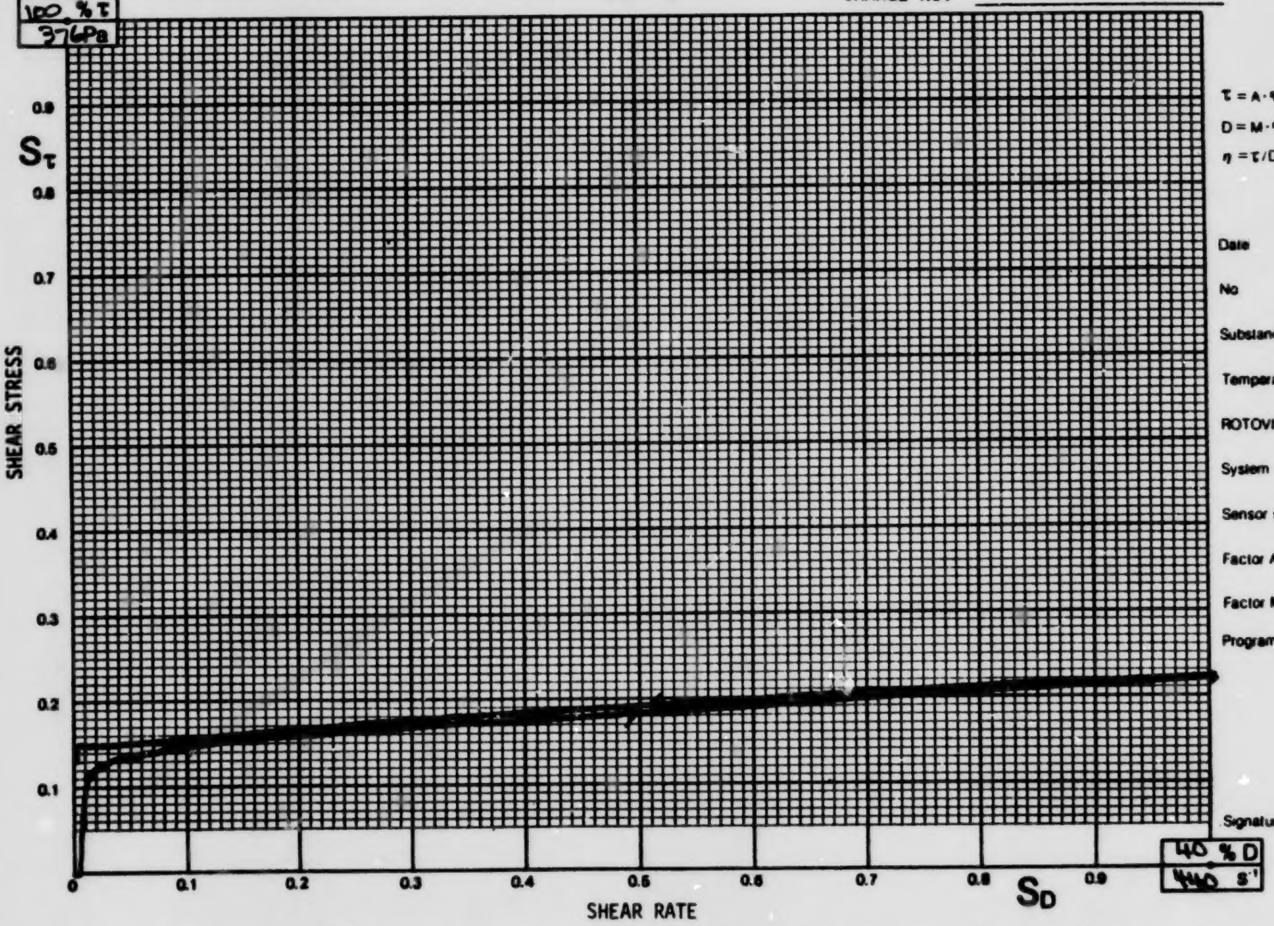
ROTOVISCO RV-100 FLOW CURVE



A =	0.150	0.170	0.179	0.186	0.192	0.201	0.210	0.219	0.227	0.231
D =	0.161	0.174	0.186	0.195	0.201	0.210	0.219	0.223	0.229	0.232

SAMPLE NO. F-2613
SAMPLE TYPE CWS 62.8
% SOLIDS
CUSTOMER
CHARGE NO.

ROTOVISCO RV-100 FLOW CURVE



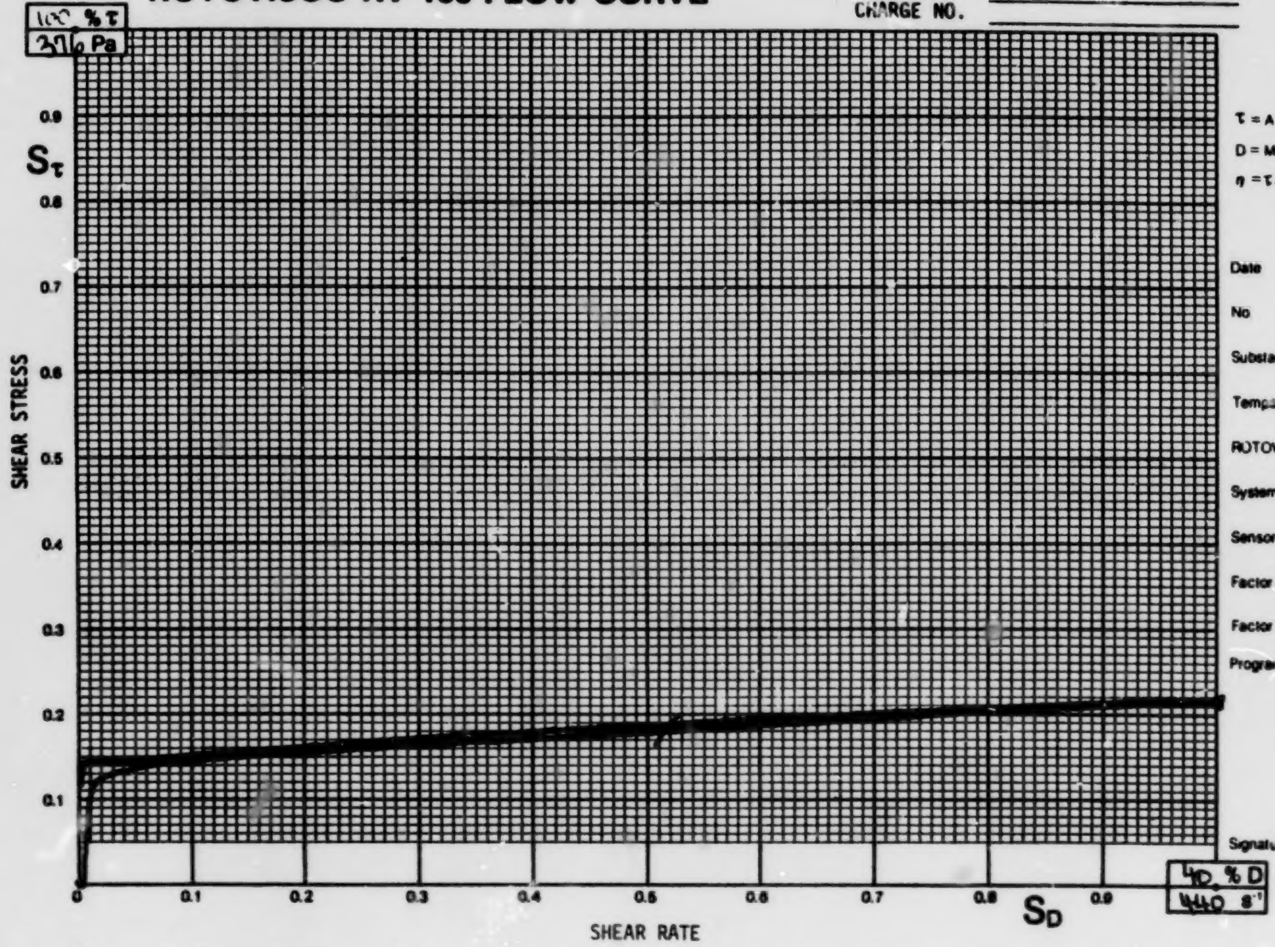
$\tau = A \cdot \%\tau \cdot S_\tau$ [Pa]
$D = M \cdot \%D \cdot S_D$ [s^{-1}]
$\eta = \tau / D$ [Pa·s]

Date [illegible]
No [illegible]
Substance [illegible]
Temperature [illegible]
ROTOVISCO RV [illegible]
System [illegible]
Sensor system [illegible]
Factor A [illegible]
Factor M [illegible]
Program times
T_1 0.1
T_2 [illegible]
T_3 [illegible]
Signature [illegible]

A =	0.148	0.159	0.169	0.174	0.182	0.190	0.200	0.206	0.212	0.220
D =	0.157	0.167	0.177	0.183	0.191	0.198	0.207	0.211	0.215	0.220

SAMPLE NO. F-2614
SAMPLE TYPE CWS 63.9
% SOLIDS
CUSTOMER
CHARGE NO.

ROTOVISCO RV-100 FLOW CURVE



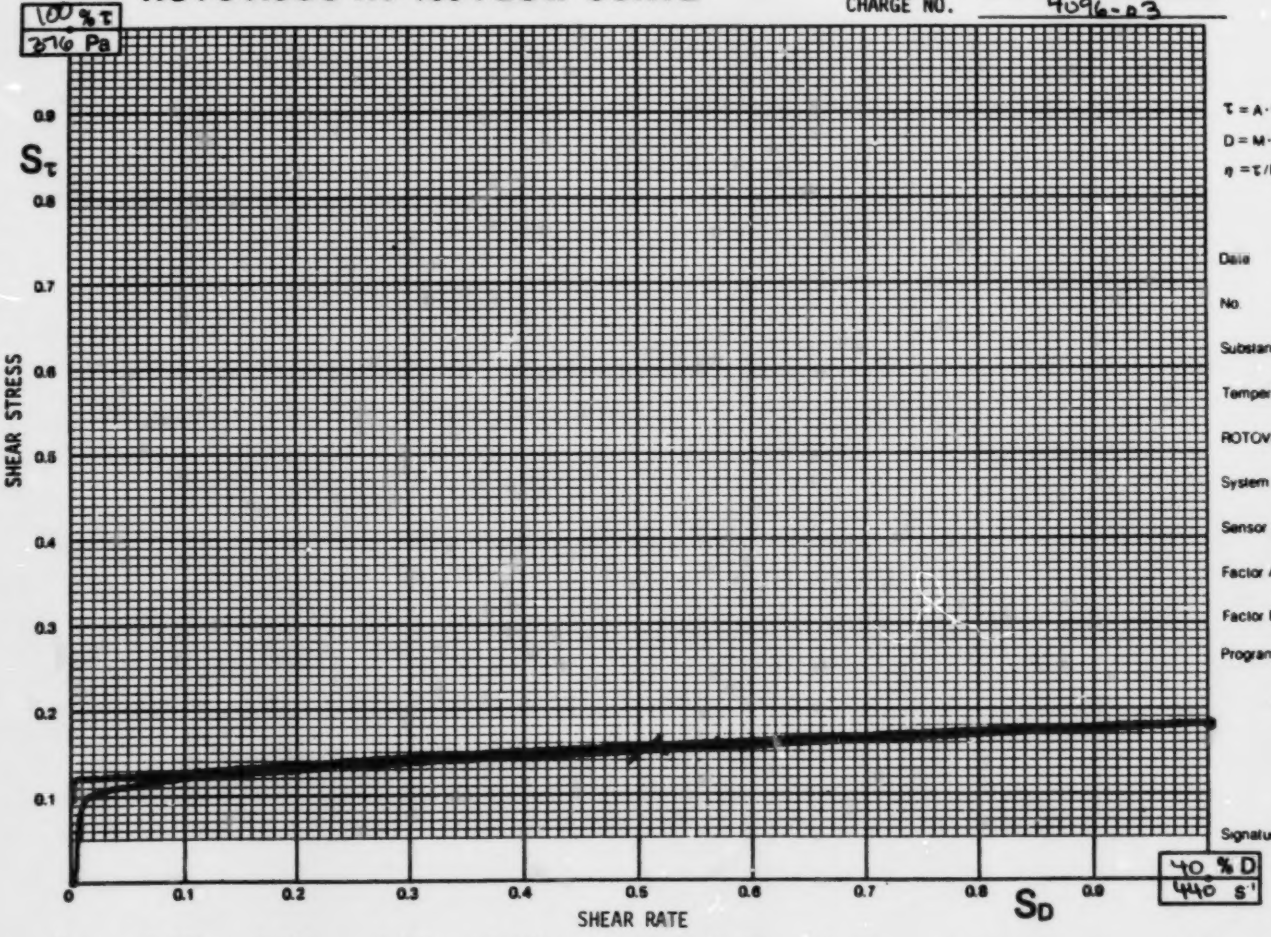
$\tau = A \cdot \%\tau \cdot S_\tau$ |Pa|
$D = M \cdot \%D \cdot S_D$ |s⁻¹|
$\eta = \tau / D$ |Pa·s|

Date [redacted]
No [redacted]
Substance [redacted]
Temperature [redacted]
ROTOVISCO RV [redacted]
System [redacted]
Sensor system [redacted]
Factor A [redacted]
Factor M [redacted]
Program times
T_1 [redacted]
T_2 [redacted]
T_3 [redacted]
Signature [redacted]

A =	0.148	0.155	0.163	0.170	0.179	0.188	0.194	0.203	0.211	0.217
D =	0.150	0.160	0.171	0.180	0.138	0.195	0.200	0.207	0.213	0.218

SAMPLE NO. F·2615
SAMPLE TYPE CWS composite
% SOLIDS
CUSTOMER
CHARGE NO. 4096-03

ROTOVISCO RV-100 FLOW CURVE



$\tau = A \cdot \%\tau \cdot S_\tau$ [Pa]
$D = M \cdot \%D \cdot S_D$ [s^{-1}]
$\eta = \tau / D$ [Pa·s]

Date [illegible]
No.
Substance CWS
Temperature [illegible]°F
ROTOVISCO RV 100
System
Sensor system [illegible]
Factor A [illegible]
Factor M [illegible]
Program times
T_1 0.1
T_2 4.0
T_3 1.0
Signature [illegible]

A =	0.120	0.130	0.138	0.143	0.150	0.158	0.162	0.170	0.179	0.182
D =	0.129	0.137	0.145	0.150	0.157	0.162	0.166	0.173	0.176	0.182

TEST SERIES 64 -- THICKENER UNDERFLOW

Sample No.	M-38387
Description	Limestone, Test #63 (Composite)
Moisture, %	0.1
Calcium as CaO, (Dry), %	50.4
Magnesium as MgO, (Dry), %	0.48
Carbonate as CO_2, (Dry), %	40.7
Calcium as $CaCO_3$ (Dry), %	90.0

Sizing

% Through 1/4"	100.0
#4	99.2
#8	95.1
#16	57.0
#30	36.4
#50	23.7
#100	15.6
#200	10.2
#325	7.1

Sample No.	F-2615
Description	Composite of Coal Slurry Samples F-2606 thru F-2614

Ash Analysis (ICP Spectrographic), %

Silicon as SiO_2	29.41
Aluminum as Al_2O_3	13.04
Iron as Fe_2O_3	30.66
Titanium as TiO_2	0.45
Calcium as CaO	6.46
Magnesium as MgO	1.52
Sodium as Na_2O*	2.16
Potassium as K_2O*	2.05
Sulfur as SO_3	10.37
Phosphorus as P_2O_5	0.33

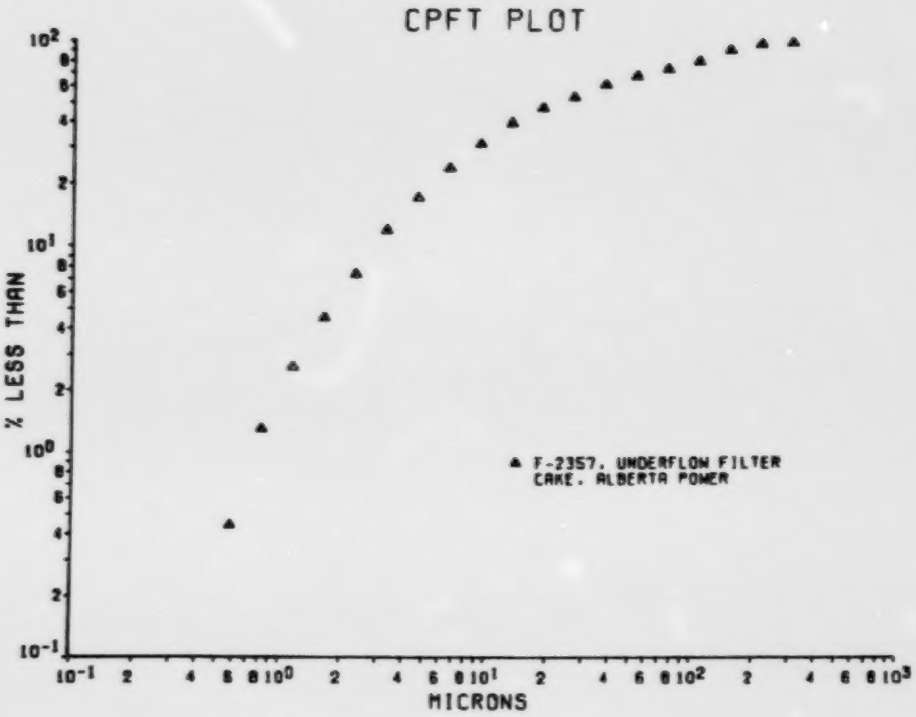
*Flame Photometer Analysis.

Sample No.	K-26728
Description	Cyclone Ash, 0700 Hrs. 9/14/83
Moisture, %	1.1
Carbon, Dry %	19.6

Sample No.	F-2357	
Description	Thickener Under Flow Filter Cake	
Basis	As Received	Dry
Total Moisture	35.6	--
Proximate Analysis, %		
Moisture	35.6	--
Volatile Matter	14.9	23.2
Fixed Carbon	17.9	27.7
Ash	31.6	49.1
Gross Heating Value Btu per Lb.	4060	6300
Btu per Lb. (M&A Free)	--	12380
Ultimate Analysis, %		
Moisture	35.6	--
Carbon	24.4	37.90
Hydrogen	1.71	2.66
Nitrogen	0.37	0.57
Sulfur	0.10	0.15
Ash	31.62	49.10
Oxygen (Difference)	6.20	9.62
	100.00	100.00

Sample No.	F-2357
Description	Thickener Under Flow Filter Cake
Ash Analysis (Spectrographic), %	
Silicon as SiO_2	62.80
Aluminum as Al_2O_3	21.95
Iron as Fe_2O_3	5.05
Titanium as TiO_2	0.47
Calcium as CaO	4.27
Magnesium as MgO	1.78
Sodium as Na_2O*	0.74
Potassium as K_2O*	1.35
Sulfur as SO_3	0.80
Phosphorus as P_2O_5	0.10

*By Flame Photometer.

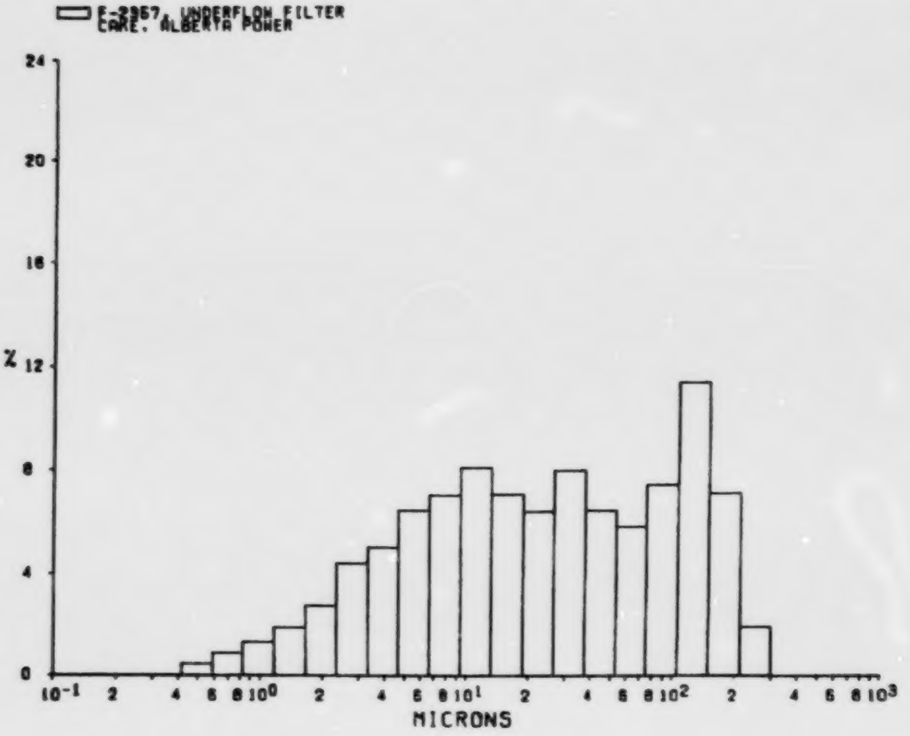


F-2357. UNDERFLOW FILTER
CAKE. ALBERTA POWER

% + 300 µm = 12.8

MICRONS	% LESS	DIFF
300.00	100.00	1.94
212.13	98.06	7.13
150.00	90.93	11.38
106.07	79.55	7.43
75.00	72.12	5.84
53.03	66.28	6.45
37.50	59.84	7.97
26.52	51.86	6.44
18.75	45.42	7.09
13.26	38.34	8.09
9.38	30.24	7.06
6.63	23.18	6.47
4.69	16.71	5.05
3.31	11.67	4.43
2.34	7.24	2.76
1.66	4.48	1.88
1.17	2.60	1.29
0.83	1.31	0.86
0.59	0.44	0.44
0.41	0.00	0.00
0.29		
0.21		
0.15		

CS(CAL SURF AREA)=0.79 M**2/CM**3
MMD(D43)=53.26 MICRONS
SMD(D32)=7.63 MICRONS


F-2957, UNDERFLOW FILTER
CAKE, ALBERTA POWER
24
20
16
%
12
8
4
0
10-1
2
4
6
8
100
2
4
6
8
101
2
4
6
8
102
2
4
6
8
103
MICRONS

Sample No.	F-2702		C-17798	
Description	Composite of Slurry Samples F-2697 through F-2701		Coal for Test 64.1 (KY #9), 10/19/83	
Basis	As Received	Dry	As Received	Dry
Total Moisture, %	69.4	--	3.0	--
Proximate Analysis, %				
Moisture	69.4	--	3.0	--
Volatile Matter	8.84	28.9		
Fixed Carbon	6.64	21.7		
Ash	15.1	49.4		
Gross Heating Value Btu per Lb.	1650	5390		
Btu per Lb. (M&A Free)	--	10652		
Ultimate Analysis, %				
Moisture	69.4	--	3.0	--
Carbon	11.5	37.7	71.2	73.4
Hydrogen	0.69	2.25		
Nitrogen	0.15	0.48		
Sulfur	0.07	0.23	2.40	2.47
Ash	15.1	49.4		
Oxygen (Difference)	3.09	9.94		
Total	100.00	100.00		

Sample No.	F-2702
Description	Composite of Coal Slurry Samples, F-2697 Through F-2701
Ash Analysis (ICP Spectrograph), %	
Silicon as SiO_2	62.45
Aluminum as Al_2O_3	20.72
Iron as Fe_2O_3	4.60
Titanium as TiO_2	0.39
Calcium as CaO	3.81
Magnesium as MgO	1.94
Sodium as Na_2O*	0.57
Potassium as K_2O*	1.31
Sulfur as SO_3	0.76
Phosphorus as P_2O_5	0.04

*Flame Photometer Analysis.

Sample No.	M-38482
Description	Sand Test 64.1
Moisture, %	0.0
Calcium as CaO, % (Dry)	<0.05
Silicon as SiO_2, % (Dry)	90.3
Carbonate as CO_2	0.02
Sizing	
% Through #8	100.0
#16	44.7
#30	3.1
#50	0.1

Sample No.	F-2697		F-2698	
Description	Coal Slurry Test 64.1 1100 Hrs.		Coal Slurry Test 64.1 1200 Hrs.	
Basis	As Received	Dry	As Received	Dry
Total Moisture, %	68.6	--	69.7	--
Solids, %	31.4	--	30.3	--
Carbon, %	11.46	36.5	11.03	36.4
Sulfur, %	0.06	0.2	0.06	0.2

Sample No.	F-2699		F-2700	
Description	Coal Slurry Test 64.1 1300 Hrs.		Coal Slurry Test 64.1 1400 Hrs.	
Basis	As Received	Dry	As Received	Dry
Total Moisture, %	69.7	--	69.6	--
Solids, %	30.3	--	30.4	--
Carbon, %	11.48	37.9	11.13	36.6
Sulfur, %	0.09	0.3	0.06	0.2

Sample No.	F-2701		F-2702	
Description	Coal Slurry Test 64.1 1500 Hrs.		Coal Slurry Test 64.1 Composite	
Basis	As Received	Dry	As Received	Dry
Total Moisture, %	70.0	--	69.4	--
Solids, %	30.0	--	30.6	--
Carbon, %	10.77	35.9	11.54	37.7
Sulfur, %	0.06	0.2	0.07	0.23

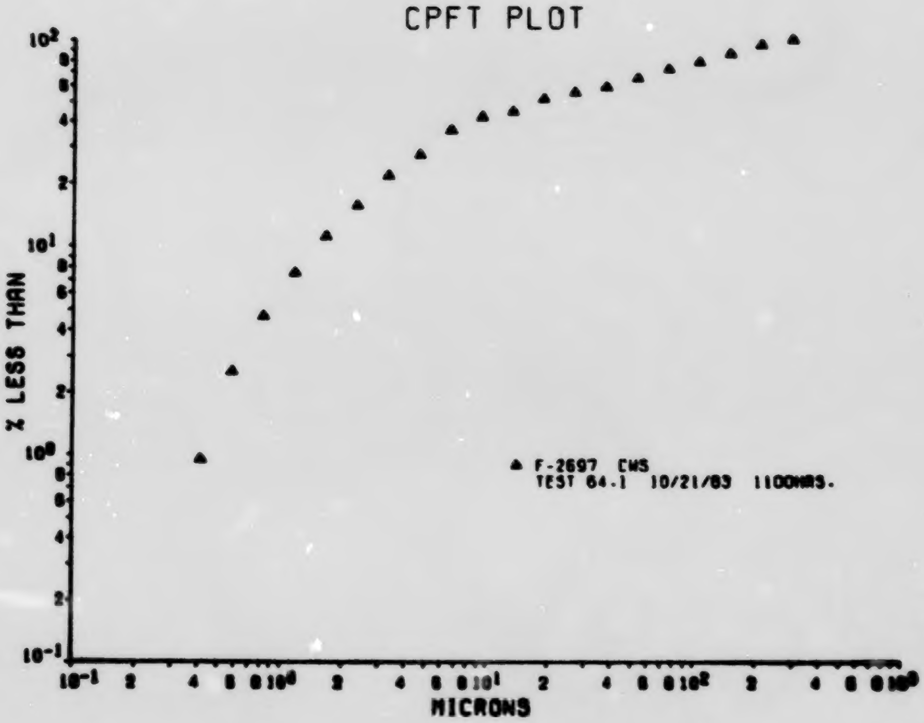
Sample No.	K-26681	K-26682	K-26683	M-38480	M-38481
Description	Cyclone Ash 1200 Hrs.	Cyclone Ash 1300 Hrs.	Baghouse Ash 1300 Hrs.	Bed Ash 1200 Hrs.	Bed Ash 1500 Hrs.
Moisture, %	1.6	0.2	3.3	N.D.	N.D.
Ash, Dry, %	84.9	91.1	87.6	100.0	100.0
Calcium as CaO, Dry, %	3.7	3.7	16.4	0.22	0.45
Sulfur as S, Dry, %	0.52	0.55	4.3	0.06	0.12
Sulfur as SO_3, Dry, %	1.30	1.37	10.7	0.15	0.30
Carbonate as CO_2, Dry, %	0.64	0.43	3.1	0.04	0.04
Carbon (ult.) Dry, % (Corr. for CO_2)	13.1	7.8	7.1	0.06	0.07

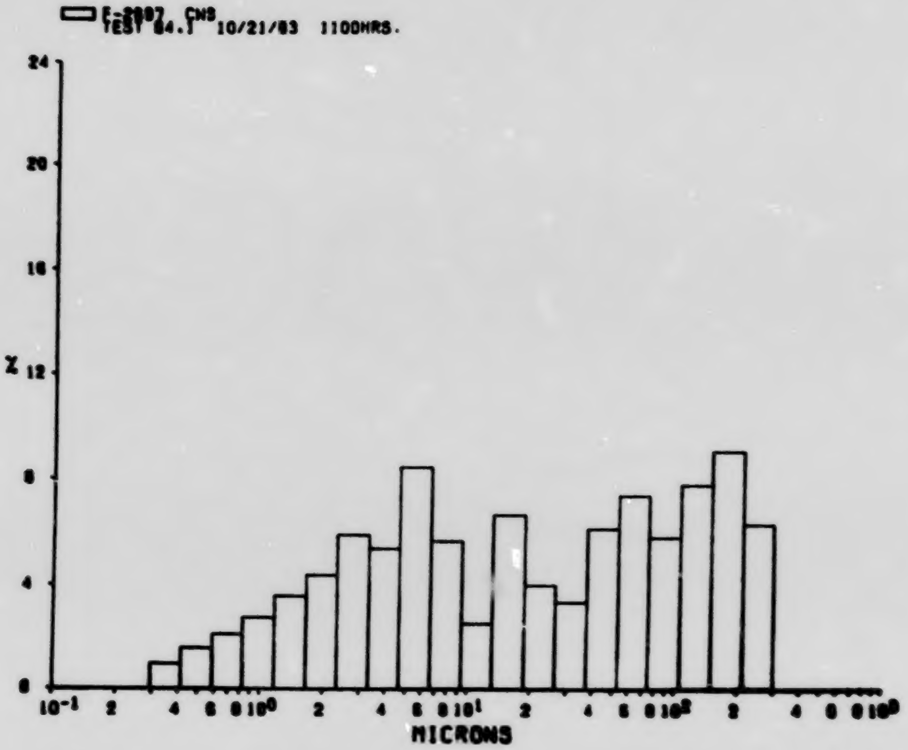
Sizing

	K-26681	K-26682	K-26683	M-38480	M-38481
% Through 1/4"			NO ANALYSIS	100.0	100.0
4M				99.7	99.7
8M				93.8	88.3
16	100.0	100.0		37.1	29.0
30	99.4	99.6		1.9	0.80
50	88.7	95.5		0.22	0.23
100	66.2	85.2		0.19	0.19
200	43.5	67.2		0.16	0.15
325	26.0	40.5		0.11	0.10

% + 300 microns = 5.48

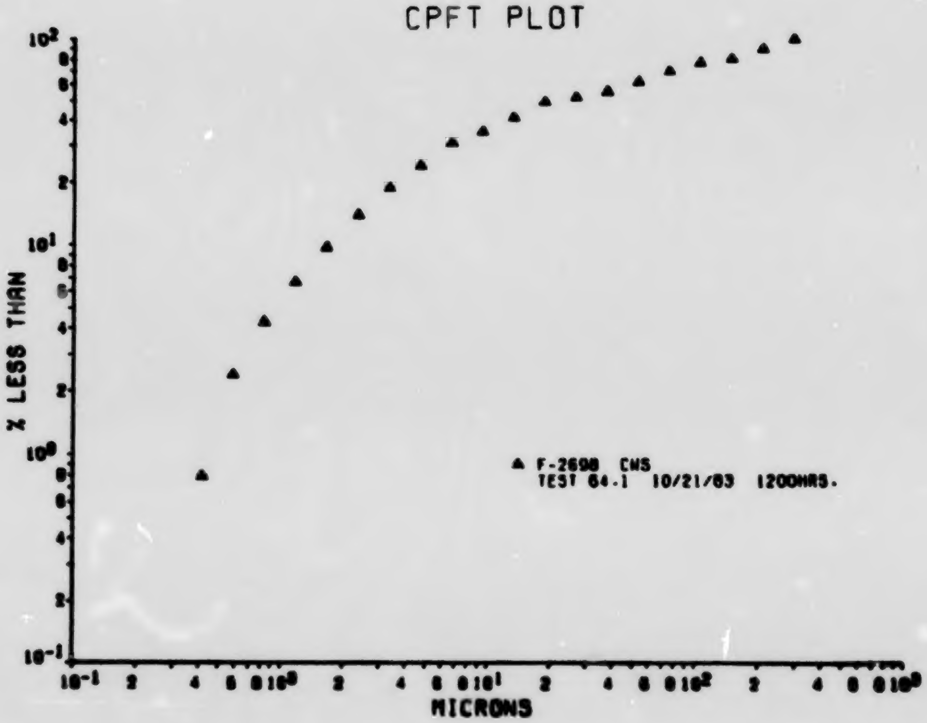
```
F-2697  CMS
TEST 64.1   10/21/83  1100HRS.

MICRONS    % LESS    DIFF

300.00     100.00    6.31
212.13      93.69    9.08
150.00      84.61    7.81
106.07      76.80    5.84
 75.00      70.96    7.39

 53.03      63.57    6.17
 37.50      57.40    3.36
 26.52      54.04    4.04
 18.75      50.00    6.68
 13.26      43.32    2.53

  9.38      40.80    5.69
  6.63      35.11    8.45
  4.69      26.66    5.40
  3.31      21.26    5.90
  2.34      15.36    4.39

  1.66      10.98    3.58
  1.17       7.38    2.77
  0.83       4.61    2.10
  0.59       2.52    1.56
  0.41       0.96    0.96

  0.29       0.00    0.00
  0.21
  0.16

           CS(CAL SURF AREA)=1.40 M**2/CM**3
           MMD(D43)=60.28 MICRONS
           SMD(D32)=4.29 MICRONS
```

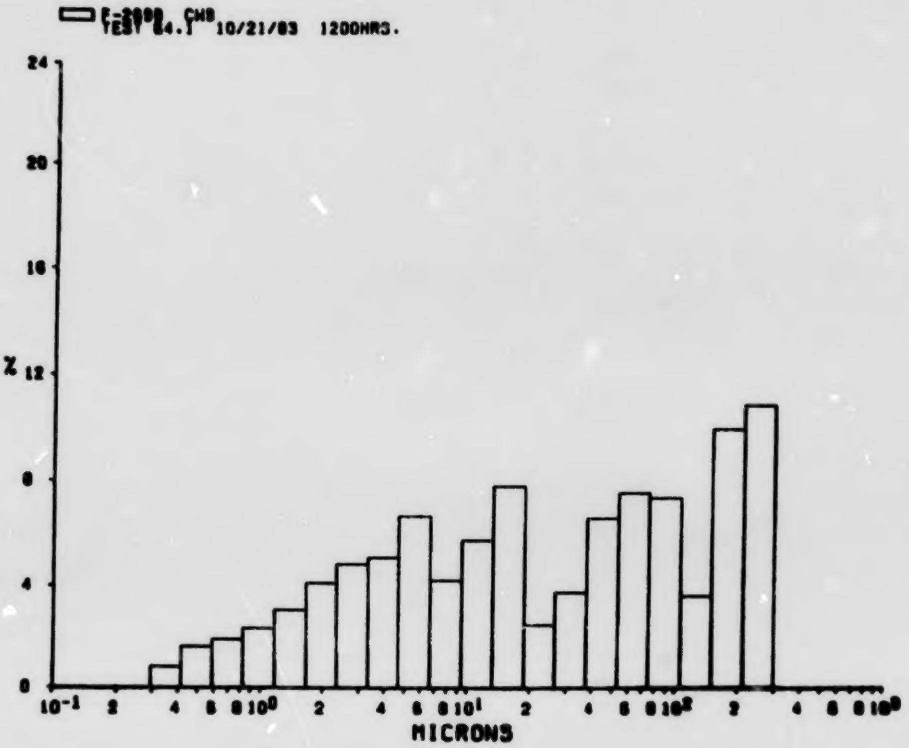



F-2807 CNS
TEST 84.1 10/21/83 1100HRS.
24
20
16
%
12
8
4
0
10⁻¹
2
4
6
8
10⁰
2
4
6
8
10¹
2
4
6
8
10²
2
4
6
8
10³
MICRONS

% + 300 microns = 5.22

```
F-2698  CMS
TEST 64.1  10/21/83  1200HRS.

MICRONS   % LESS   DIFF

300.00    100.00   10.83
212.13     89.17    9.91
150.00     79.26    3.58
106.07     75.68    7.35
 75.00     68.33    7.51

 53.03     60.81    6.59
 37.50     54.23    3.73
 26.52     50.50    2.47
 18.75     48.03    7.78
 13.26     40.26    5.76

  9.38     34.50    4.20
  6.63     30.30    6.64
  4.69     23.66    5.09
  3.31     18.57    4.81
  2.34     13.76    4.11

  1.66      9.64    3.04
  1.17      6.60    2.33
  0.83      4.27    1.88
  0.59      2.39    1.60
  0.41      0.79    0.79

  0.29      0.00    0.00
  0.21
  0.15

          CS(CAL SURF AREA)=1.26 M**2/CM**3
          MMD(D43)=88.58 MICRONS
          SMD(D32)=4.78 MICRONS
```



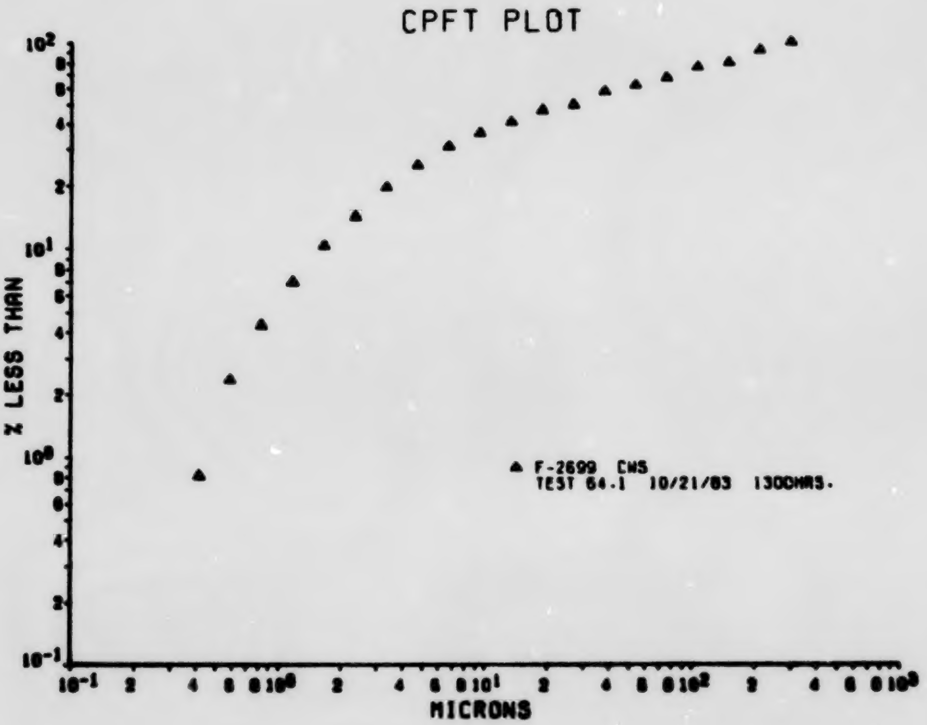

F-2000 CHB
TEST 84.1 10/21/83 1200HRS.
24
20
16
%
12
8
4
0
10⁻¹
2
4
6
8
10⁰
2
4
6
8
10¹
2
4
6
8
10²
2
4
6
8
10³
MICRONS

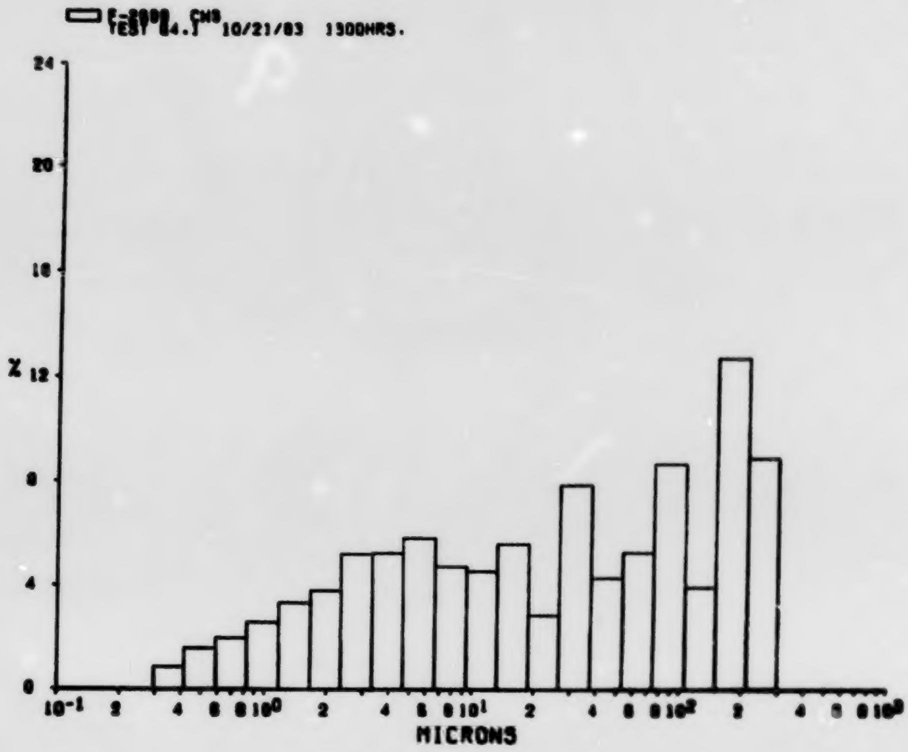
% + 300 microns = 4.66

F-2699 CMS
TEST 64.1 10/21/83 1300HRS.

MICRONS	% LESS	DIFF
300.00	100.00	8.91
212.13	91.09	12.73
150.00	78.36	3.95
106.07	74.41	8.68
75.00	65.74	5.32
53.03	60.42	4.31
37.50	56.11	7.88
26.52	48.24	2.88
18.75	45.36	5.63
13.26	39.73	4.59
9.38	35.14	4.74
6.63	30.38	5.81
4.69	24.57	5.27
3.31	19.30	5.23
2.34	14.06	3.81
1.66	10.25	3.34
1.17	6.91	2.59
0.83	4.31	1.95
0.59	2.36	1.54
0.41	0.82	0.82
0.29	0.00	0.00
0.21		
0.15		

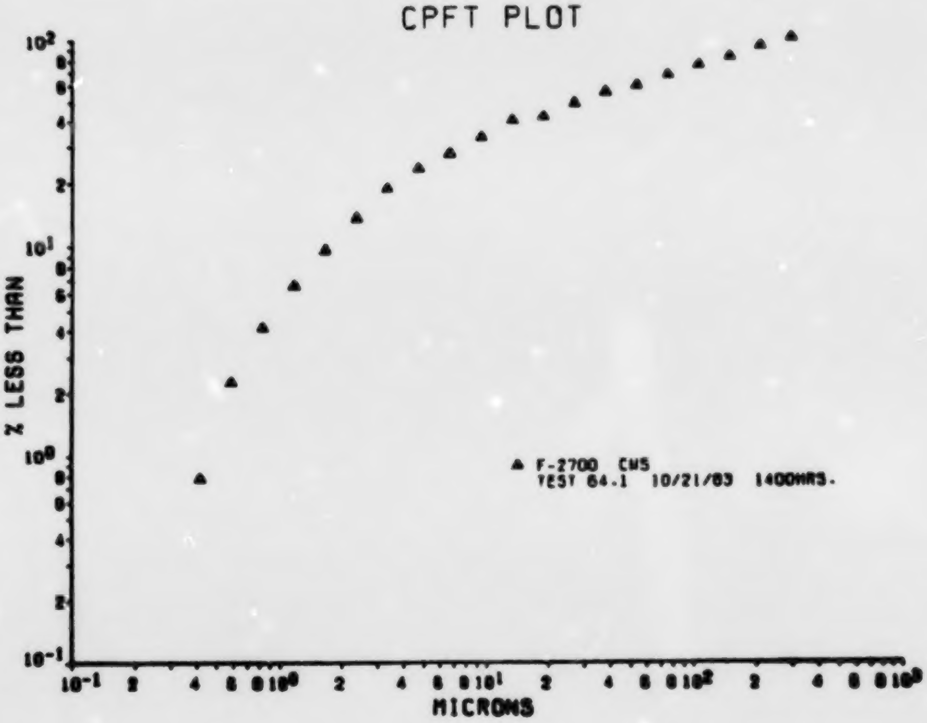
CS(CAL SURF AREA)=1.28 M**2/CM**3
MMD(D43)=69.96 MICRONS
SMD(D32)=4.68 MICRONS

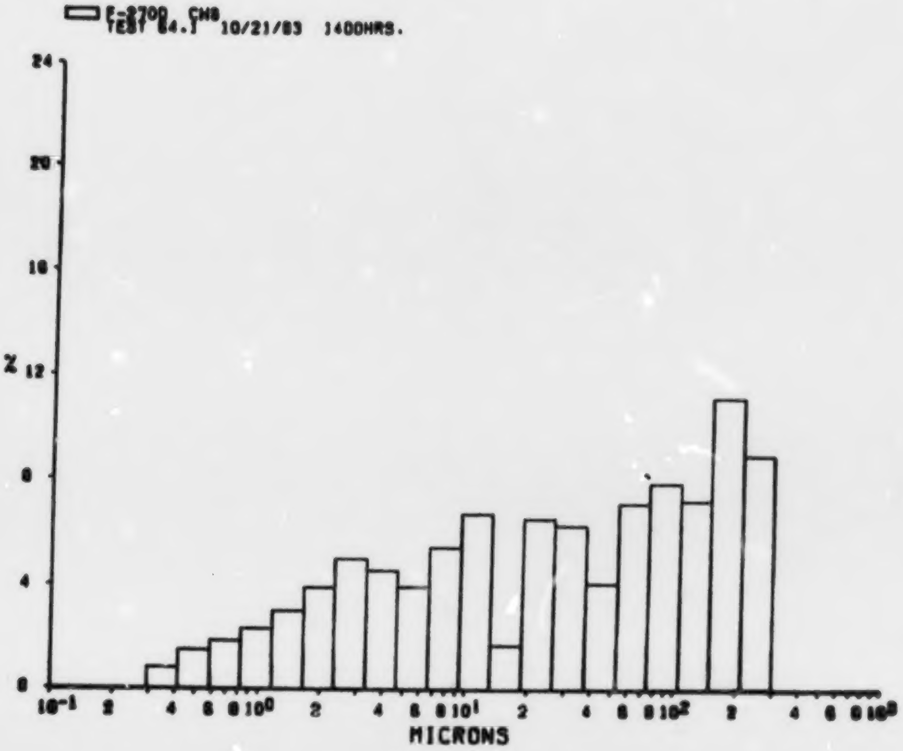



E-2000 CMS
TEST 64.1 10/21/83 1300HRS.
%
0
4
8
12
16
20
24
10^{-1}
2
4
6
8
10^{0}
2
4
6
8
10^{1}
2
4
6
8
10^{2}
2
4
6
8
10^{3}
MICRONS

% + 300 microns = 4.29

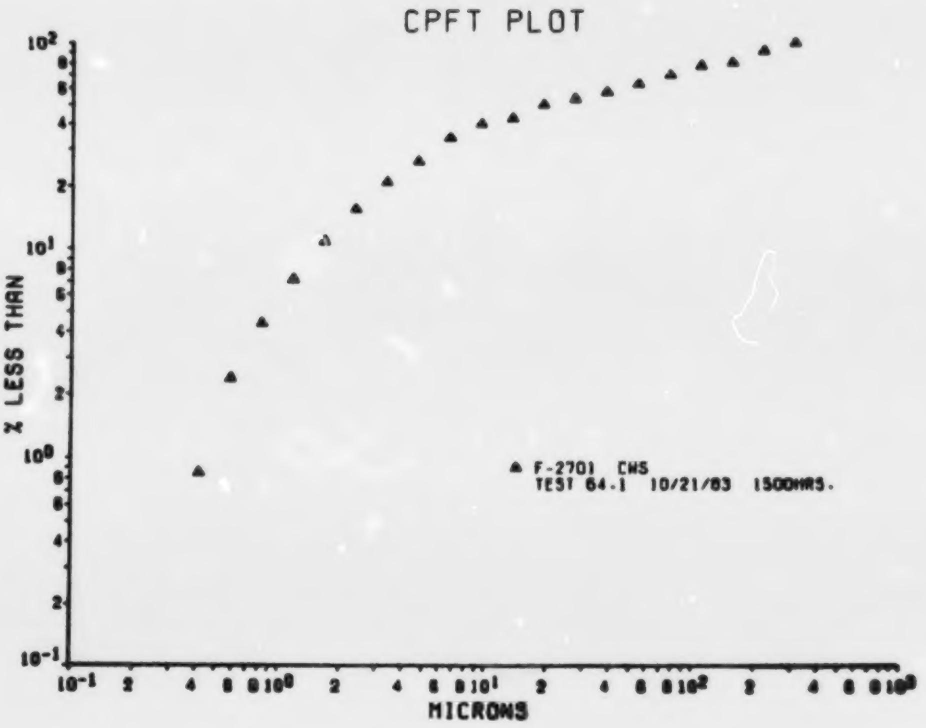
```
F-2700  CMS
TEST 64.1   10/21/83   1400HRS.

MICRONS    % LESS     DIFF

300.00     100.00     8.93
212.13      91.07    11.14
150.00      79.93     7.22
106.07      72.71     7.88
 75.00      64.83     7.13

 53.03      57.70     4.12
 37.50      53.58     6.28
 26.52      47.30     6.55
 18.75      40.75     1.70
 13.26      39.05     6.71

  9.38      32.34     5.46
  6.63      26.89     3.95
  4.69      22.94     4.56
  3.31      18.38     5.02
  2.34      13.36     3.90

  1.66       9.46     3.00
  1.17       6.46     2.33
  0.83       4.12     1.85
  0.59       2.26     1.48
  0.41       0.78     0.78

  0.29       0.00     0.00
  0.21
  0.15

           CS(CAL SURF AREA)=1.21 M**2/CM**3
           MMD(D43)=71.62 MICRONS
           SMD(D32)=4.07 MICRONS
```

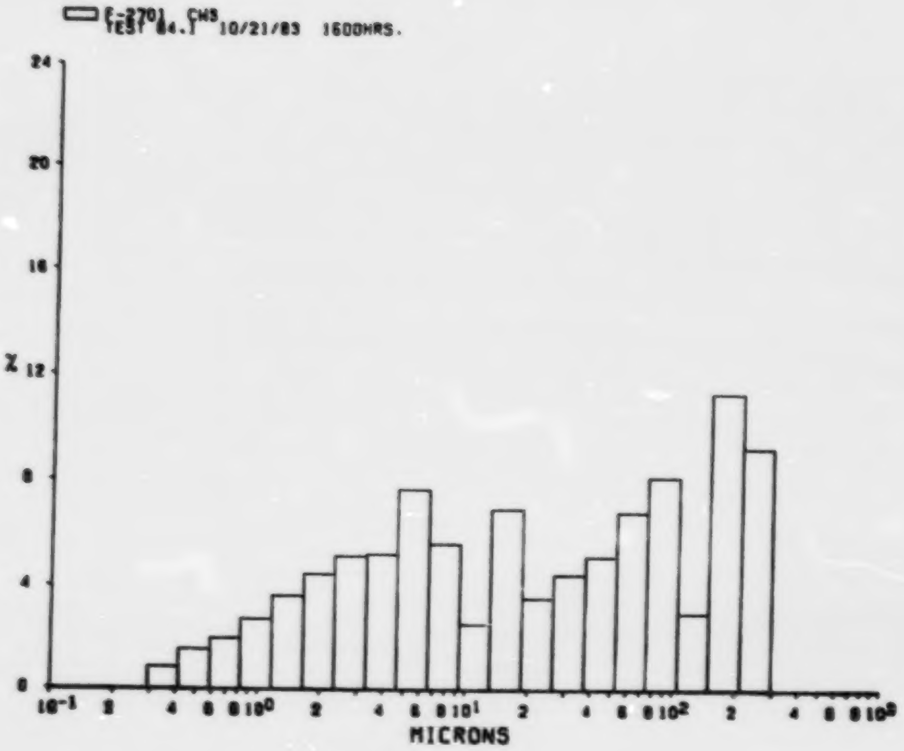



F-2700 CHB
TEST 84.1 10/21/83 1400HRS.
24
20
16
%
12
8
4
0
10^{-1}
2
4
6
8
10^0
2
4
6
8
10^1
2
4
6
8
10^2
2
4
6
8
10^3
MICRONS

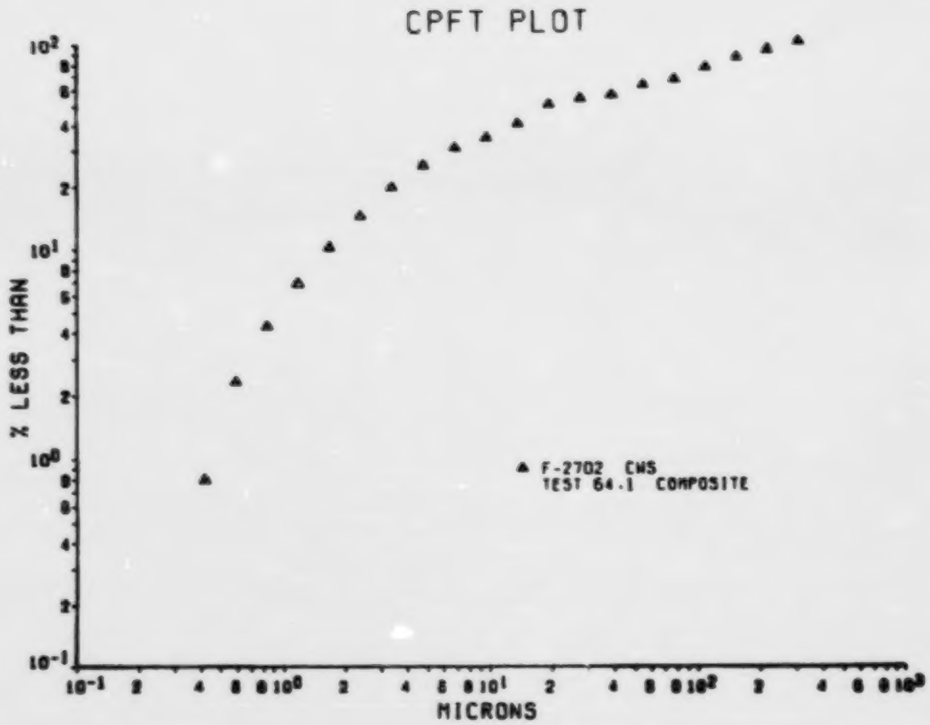
% + 300 microns = 4.39

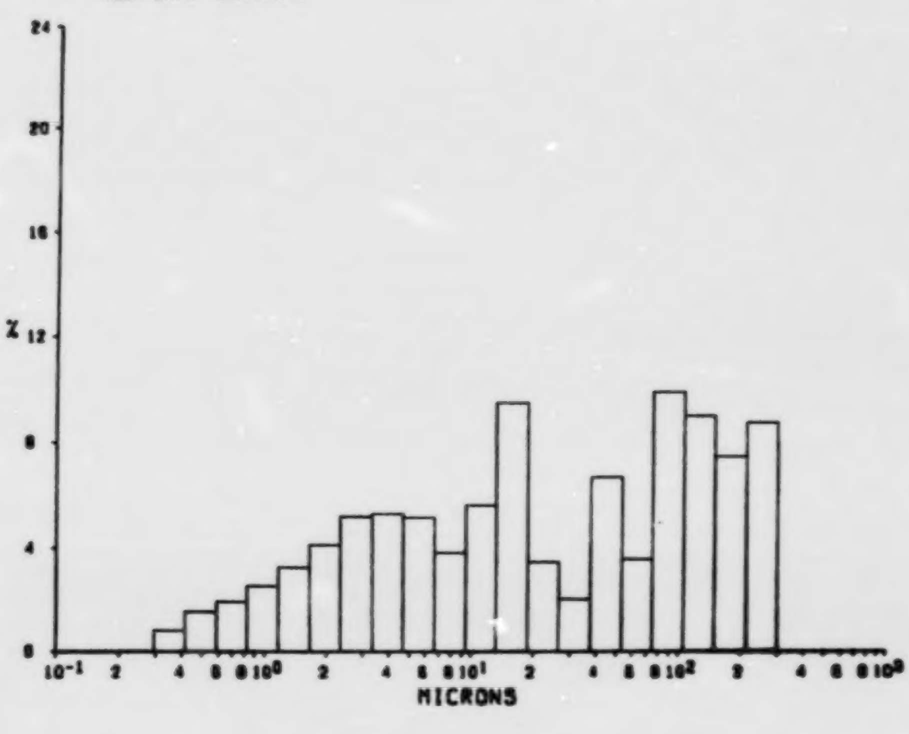
```
F-2701  CMS
TEST 64.1   10/21/83   1500HRS.

MICRONS   % LESS    DIFF

300.00    100.00     9.22
212.13     90.78    11.31
150.00     79.47     2.99
106.07     76.48     8.13
 75.00     68.35     6.83

 53.03     61.53     5.16
 37.50     56.37     4.47
 26.52     51.90     3.55
 18.75     48.35     6.95
 13.26     41.40     2.56

  9.38     38.84     5.62
  6.63     33.23     7.68
  4.69     25.55     5.23
  3.31     20.32     5.15
  2.34     15.17     4.47

  1.66     10.70     3.64
  1.17      7.06     2.72
  0.83      4.34     1.96
  0.59      2.38     1.53
  0.41      0.85     0.85

  0.29      0.00     0.00
  0.21
  0.15

          CS(CAL SURF AREA)=1.34 M**2/CM**3
          MMD(D43)=67.04 MICRONS
          SMD(D32)=4.48 MICRONS
```




E-2701, CH3
TEST 84.1 10/21/83 1600HRS.
24
20
16
%
12
8
4
0
10-1
2
4
6
8
10^0
2
4
6
8
10^1
2
4
6
8
10^2
2
4
6
8
10^3
MICRONS

```
% + 300 microns = 4.70

F-2702  CHS
TEST 64.1   COMPOSITE

MICRONS    % LESS     DIFF

300.00     100.00     8.76
212.13      91.24     7.47
150.00      83.77     9.02
106.07      74.74     9.93
 75.00      64.81     3.59

 53.03      61.22     6.73
 37.50      54.49     2.03
 26.52      52.46     3.50
 18.75      48.96     9.50
 13.26      39.46     5.67

  9.38      33.79     3.84
  6.63      29.95     5.20
  4.69      24.75     5.35
  3.31      19.40     5.23
  2.34      14.18     4.12

  1.66      10.05     3.28
  1.17       6.77     2.52
  0.83       4.24     1.93
  0.59       2.31     1.51
  0.41       0.80     0.80

  0.29       0.00     0.00
  0.21
  0.15

           CS(CAL SURF AREA)=1.28 M**2/CM**3
           MMD(D43)=66.60 MICRONS
           SMD(D32)=4.70 MICRONS
```

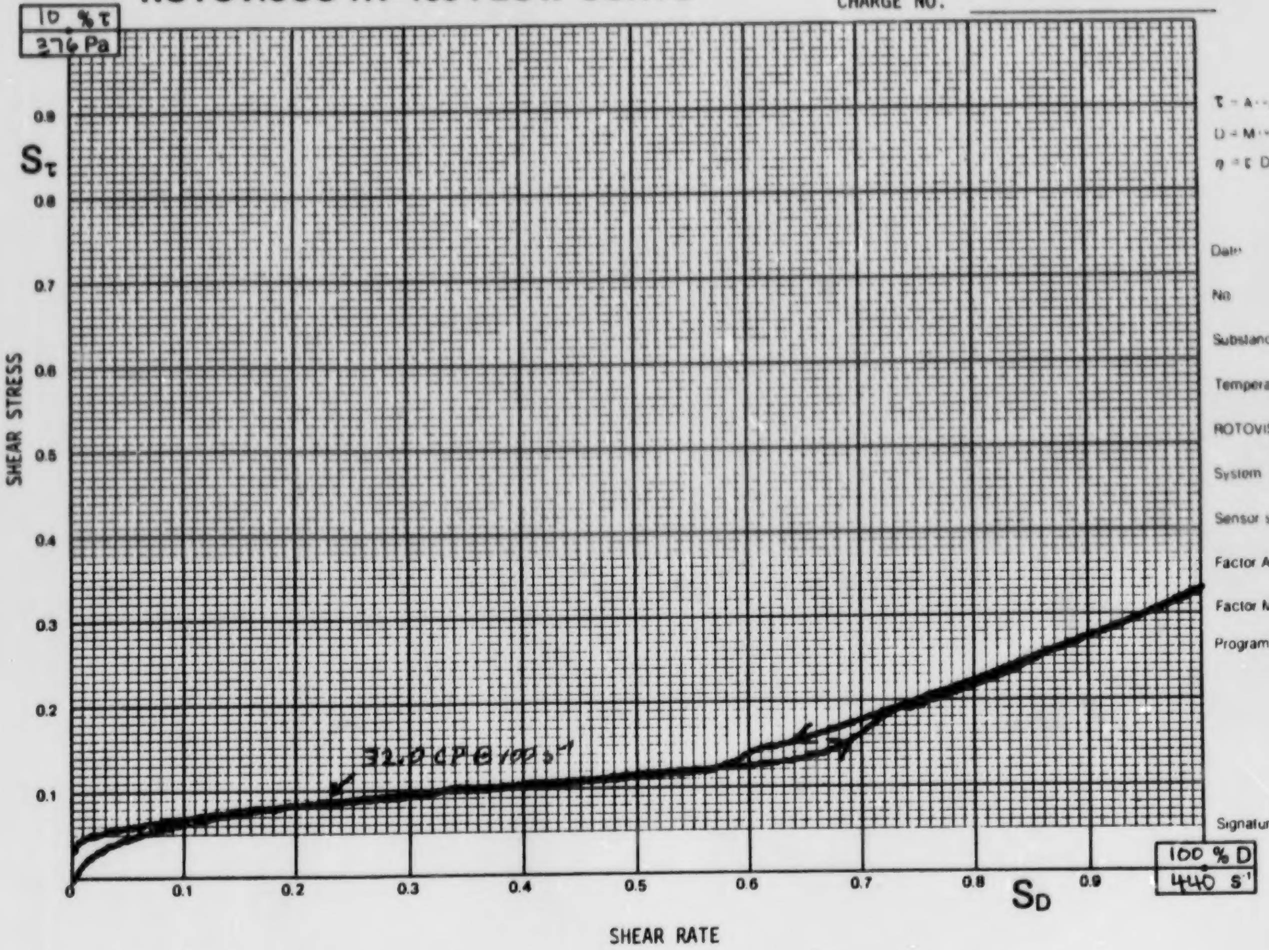




F-2702, CH9
TEST 64.1 COMPOSITE
24
20
16
%
12
8
4
0
10^{-1}
2
4
6
8
10^0
2
4
6
8
10^1
2
4
6
8
10^2
2
4
6
8
10^3
MICRONS

ROTOVISCO RV-100 FLOW CURVE

SAMPLE NO. F-2697
SAMPLE TYPE test 64.1 10/21/83
% SOLIDS
CUSTOMER
CHARGE NO.

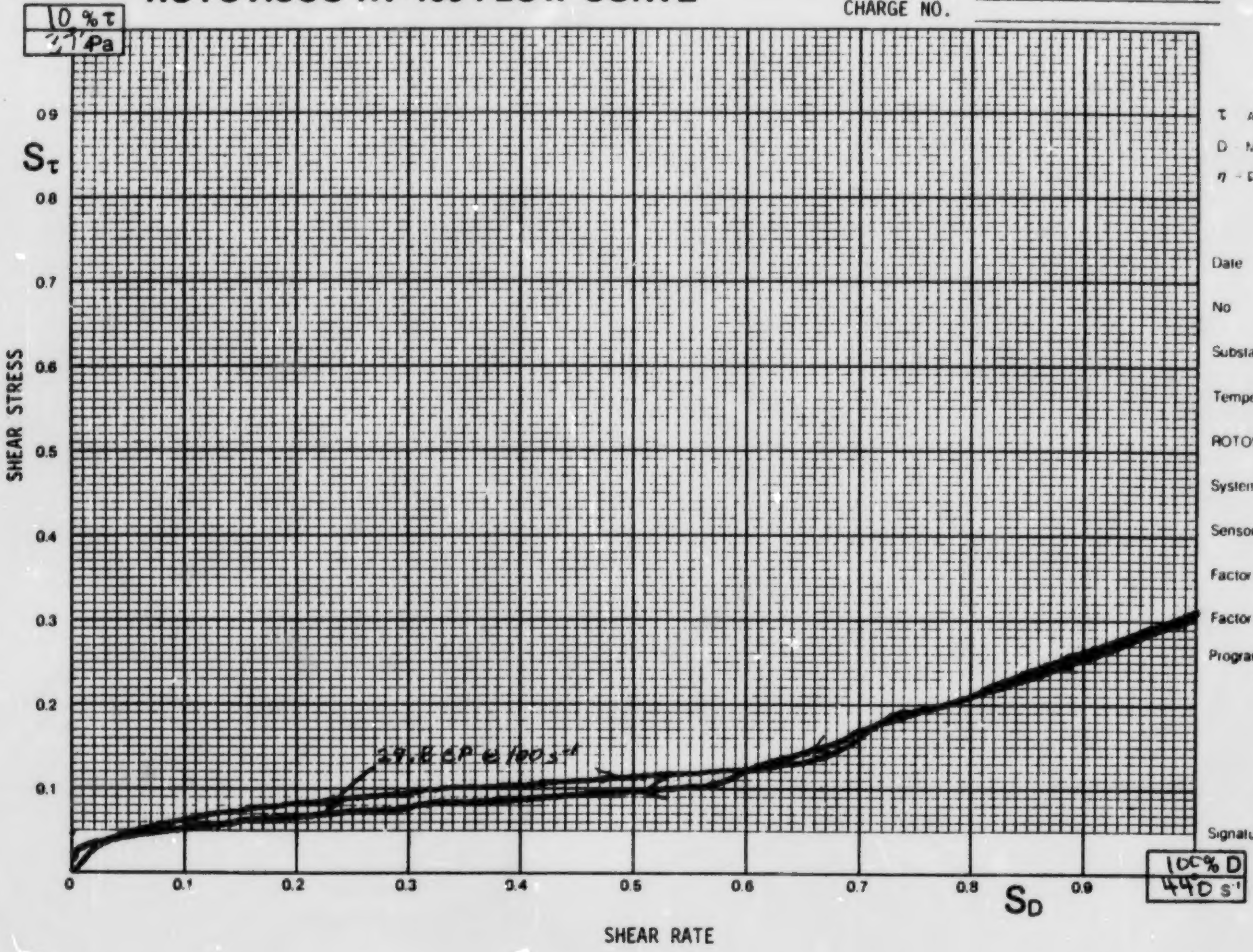


$\tau = A \cdot \%\tau \cdot S_\tau$ [Pa]
$D = M \cdot \%D \cdot S_D$ [s^{-1}]
$\eta = \tau / D$ [Pa·s]

Date	11-8-83
No	
Substance	CWS
Temperature	80°F
ROTOVISCO RV	100
System	
Sensor system	MVIIP
Factor A	3.76
Factor M	4.40
Program times	
T_1	0
T_2	4.0
T_3	0
Signature	

ROTOVISCO RV-100 FLOW CURVE

SAMPLE NO. F-2698
SAMPLE TYPE test 64.1 10/21/83
% SOLIDS
CUSTOMER
CHARGE NO.



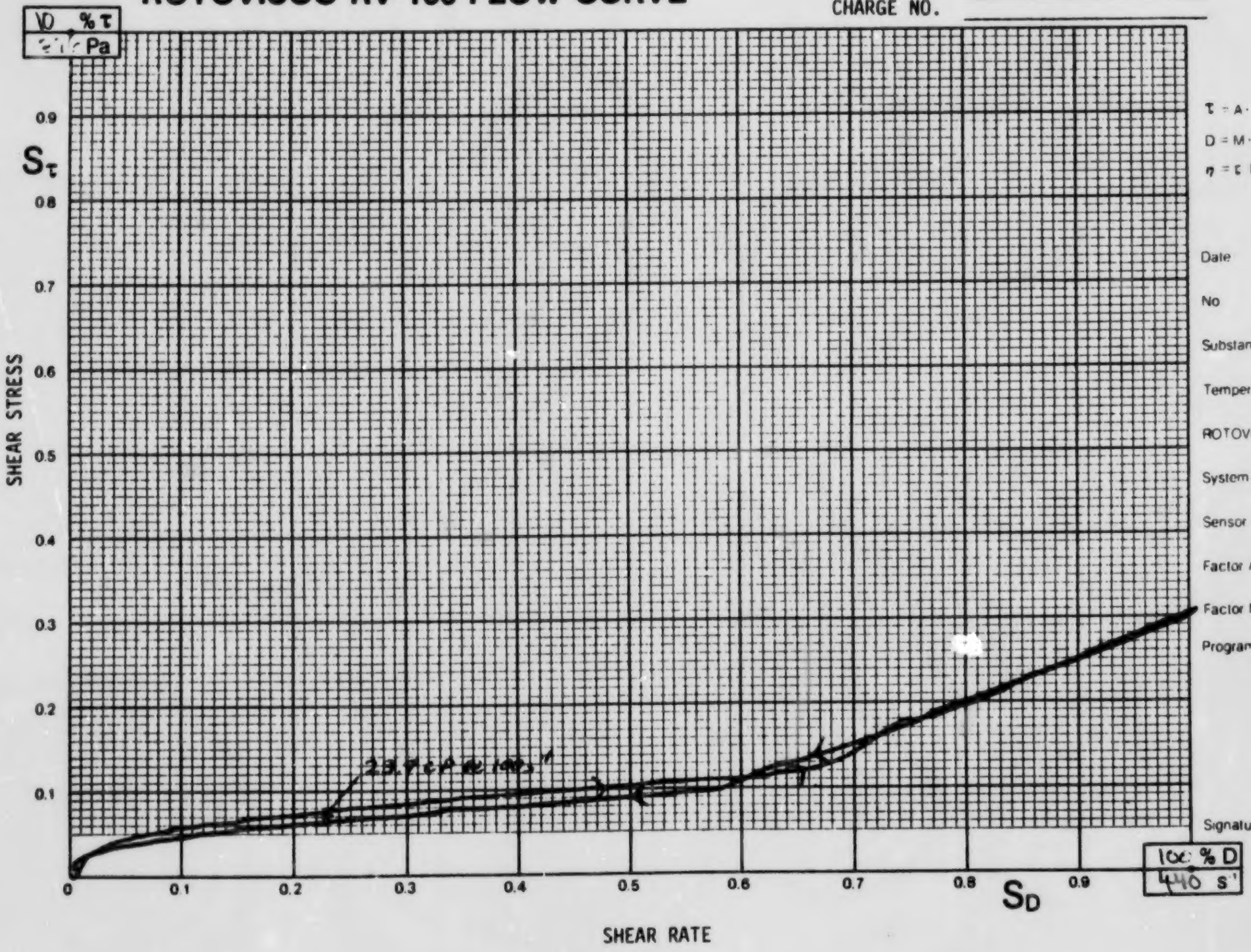
27.8 cP @ 100 s⁻¹

$\tau = A \cdot \%\tau \cdot S_\tau$ [Pa]
$D = M \cdot \%D \cdot S_D$ [s⁻¹]
$\eta = \tau / D$ [Pa·s]

Date 11-8-83
No
Substance Cass
Temperature 80°F
ROTOVISCO RV 100
System
Sensor system MV-II P
Factor A 3.76
Factor M 4.40
Program times
T_1 0
T_2 4.0
T_3 0
Signature

ROTOVISCO RV-100 FLOW CURVE

SAMPLE NO. F-2699
SAMPLE TYPE test 64.1 10/21/83
% SOLIDS
CUSTOMER
CHARGE NO.

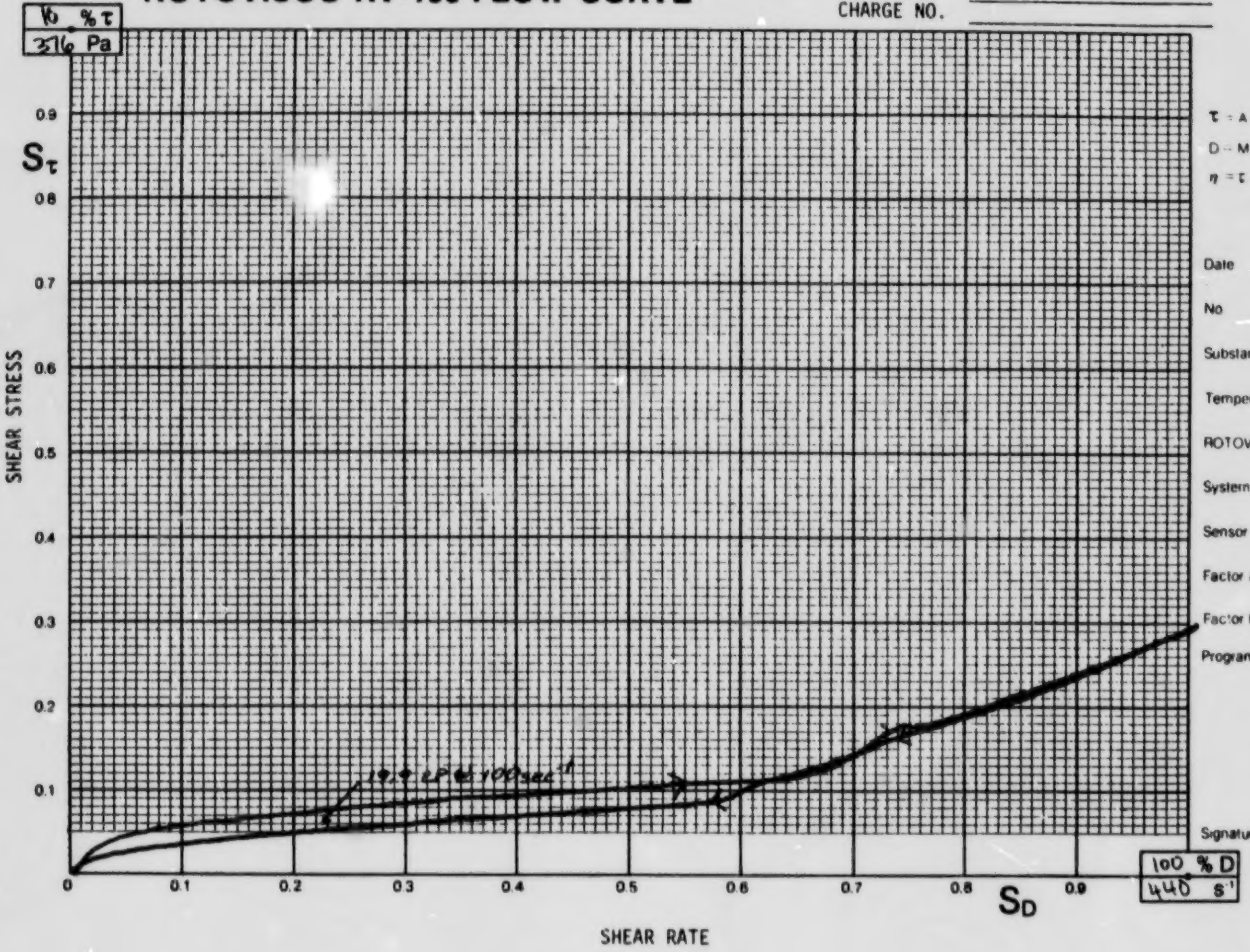


$\tau = A \cdot \%\tau \cdot S_\tau$ (Pa)
$D = M \cdot \%D \cdot S_D$ (s⁻¹)
$\eta = \tau / D$ (Pa·s)

Date	11-1-83
No	
Substance	CWS
Temperature	80°F
ROTOVISCO RV	100
System	
Sensor system	MV II P
Factor A	3.76
Factor M	4.40
Program times	
T_1	0
T_2	1.0
T_3	0
Signature	MSD

SAMPLE NO. F-2700
SAMPLE TYPE test 64.1 10/21/83
% SOLIDS
CUSTOMER
CHARGE NO.

ROTOVISCO RV-100 FLOW CURVE

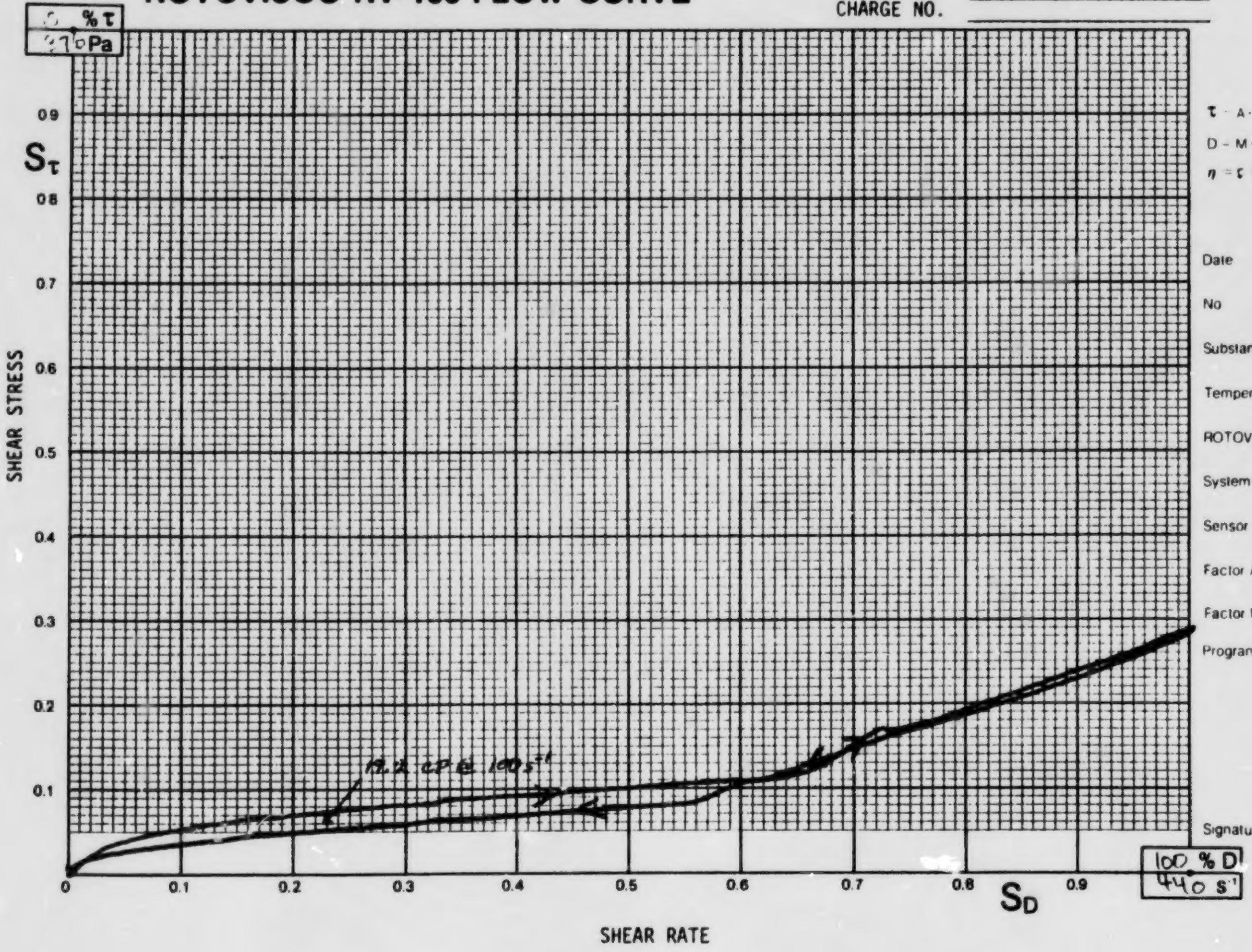


$\tau = A \cdot \%\tau \cdot S_\tau$ [Pa]
$D = M \cdot \%D \cdot S_D$ [s⁻¹]
$\eta = \tau / D$ [Pa·s]

Date	11-8-83
No	
Substance	CWS
Temperature	80°F
ROTOVISCO RV	100
System	
Sensor system	MV II
Factor A	3.76
Factor M	4.40
Program times	
T_1	0
T_2	4.0
T_3	0
Signature	

ROTOVISCO RV-100 FLOW CURVE

SAMPLE NO. F-2701
SAMPLE TYPE Test 64.1 10/21/83
% SOLIDS
CUSTOMER
CHARGE NO.

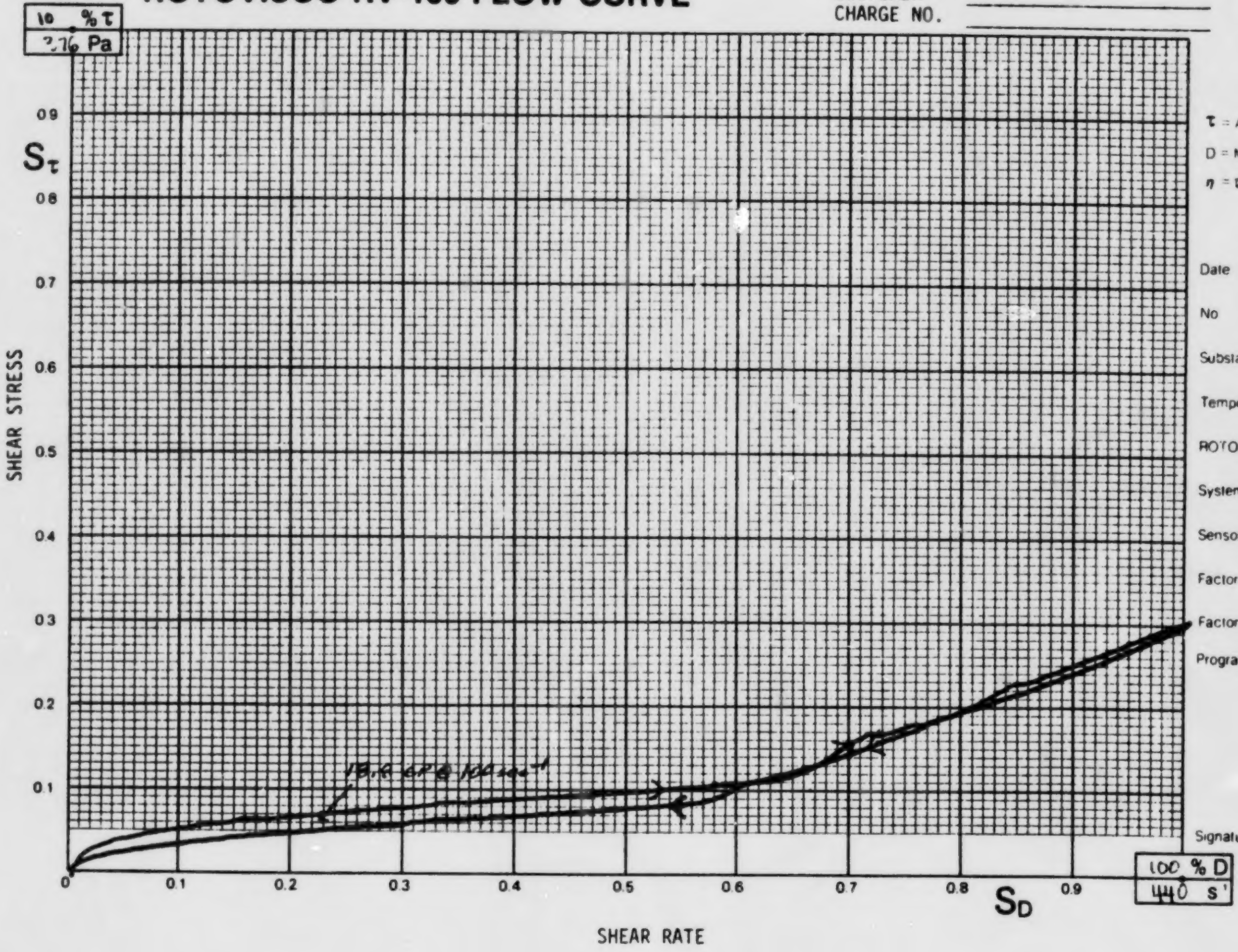


$\tau = A \cdot \%\tau \cdot S_\tau$ [Pa]
$D = M \cdot \%D \cdot S_D$ [s⁻¹]
$\eta = \tau / D$ [Pa·s]

Date	11-8-83
No	
Substance	CWS
Temperature	80°F
ROTOVISCO RV	100
System	
Sensor system	MV II P
Factor A	3.76
Factor M	4.40
Program times	
T_1	0
T_2	4.0
T_3	0
Signature	WGS

SAMPLE NO. F-2702
SAMPLE TYPE test 64.1 Composite
% SOLIDS
CUSTOMER
CHARGE NO.

ROTOVISCO RV-100 FLOW CURVE



$\tau = A \cdot \%\tau \cdot S_\tau$ [Pa]
$D = M \cdot \%D \cdot S_D$ [s⁻¹]
$\eta = \tau / D$ [Pa·s]

Date 11-9-83
No
Substance Cuts
Temperature 80°F
ROTOVISCO RV 100
System
Sensor system MV III P
Factor A 3.76
Factor M 4.40
Program times
T_1 0
T_2 4.0
T_3 0
Signature

Appendix B

REDUCED PERFORMANCE DATA

Test Series 62 -- Carbogel Beneficiated CWS . . . . Page B-1

Test Series 63 -- Scotia-Liquicoal Unbeneficiated CWS . . . . Page B-21

Test Series 64 -- Thickener Underflow . . . . Page B-39

TEST SERIES 62 -- CARBOGEL BENEFICIATED CWS

NOTE: As a consequence of the low sulfur content of the beneficiated fuel used in Test Series 62, the required limestone input rate was very low (1 - 4 lbs/hr). Since the limestone feeder was designed for higher flow rates, some inaccuracy was introduced when operating in this low range. Therefore, the limestone rates reported on the following data sheets (Series 62) are calculated adjustments to the actual measured rates. The rates were adjusted to maintain a reasonable calcium balance.

TEST NUMBER =62.01　　TEST DATE = 8/4/83　　TEST TIME = 0930-1230

MATERIAL BALANCE (LBS/HR)

	TOTAL	CARBON	SULFUR	CALCIUM
FUEL	56.4	34.5	0.30	0.01
LIMESTONE	1.9	0.2	0.00	0.67
FLUIDIZING AIR	426.5			
TRANSPORT AIR	90.6			
PURGE AIR	16.7			
PROBE AIR	32.2			
RECYCLE AIR	0.0			
TOTAL IN	624.2	34.7	0.30	0.68
BED LETDOWN	0.0	0.0	0.00	0.00
CYCLONE HOPPER OVERFLOW	5.3	2.7	0.11	0.58
CYCLONE OUTLET DUST	0.4	0.1	0.02	0.05
FLUE GAS	619.7	31.9*	0.14	
TOTAL OUT	625.4	34.7	0.26	0.62
% ACCOUNTED FOR	100.2	100.0	87.0	92.2

* CO2 IN FLUE GAS CALCULATED BY DIFFERENCE

CHEMICAL ANALYSIS (WT. PERCENT)

FUEL TYPE	H2O*	C*	H	N	S*	O	ASH	BTU/LB
BENE. CWS	28.10	61.10	3.98	1.15	0.54	3.87	1.05	10890.

LIMESTONE TYPE	H2O	C(DRY%)	CAO(DRY%)	MGO(DRY%)	SO3(DRY%)	CO2(DRY%)
REED	0.20		50.10	0.70	0.00	40.80
BED LETDOWN	0.00	0.00	51.60		30.30	0.30
CYCLONE HOPPER OVERFLOW	1.20	51.50	15.40		5.30	1.90
CYCLONE OUTLET DUST	3.20	12.00	16.30		10.00	3.10

* C, S, AND H2O MEASURED FOR EACH TEST
H, N, O, ASH, AND BTU/LB BASED ON COMPOSITE OF ALL TESTS

```
TEST NUMBER =62.01      TEST DATE = 8/4/83        TEST TIME = 0930-1230


SUMMARY OF RESULTS

     SUPERFICIAL VELOCITY
        BASED ON AIR                              6.0  FT/SEC
        BASED ON FLUE GAS                         6.7  FT/SEC

     EXCESS AIR                                  16.0  PCT

     CALCIUM/SULFUR RATIO                         1.8

     CARBON CONVERSION                           92.0  PCT

     COMBUSTION EFFICIENCY                       93.5  PCT

     SULFUR CAPTURE                              54.9  PCT
     (NORMALIZED)                                48.2  PCT

     CALCIUM UTILIZATION
        IN SPENT BED                             41.1  PCT
        IN CYCLONE ASH                           24.1  PCT
        IN BAGHOUSE ASH                          42.9  PCT


     O2 CONCENTRATION =     3.0  PCT
     SO2 CONCENTRATION(3% O2) =   209.   PPM            0.45  LB/MBTU
     NOX CONCENTRATION(3% O2) =   267.   PPM            0.37  LB/MBTU
     CO CONCENTRATION(3% O2) =    203.   PPM            0.17  LB/MBTU


     AVERAGE BED TEMPERATURE =        1562.   DEGREES F
     FREEBOARD #1 TEMPERATURE =       1585.   DEGREES F
     FREEBOARD #2 TEMPERATURE =       1631.   DEGREES F
     FREEBOARD #3 TEMPERATURE =       1544.   DEGREES F
     FREEBOARD #4 TEMPERATURE =        986.   DEGREES F
     PREHEAT TEMPERATURE =             397.   DEGREES F


     FUEL FEED RATE =         56.4  LBS/HR
     LIMESTONE FEED RATE =     1.9  LBS/HR
     FINES RECYCLE RATE =      0.0  LBS/HR
     FINES RECYCLE RATIO =     0.0


     PLATE DP =                6.1  IN H2O
     BED DP =                 20.3  IN H2O
     BED HEIGHT =             25.8  INCHES
```

TEST NUMBER =62.02 TEST DATE = 8/4/83 TEST TIME = 1330-1630

MATERIAL BALANCE (LBS/HR)

	TOTAL	CARBON	SULFUR	CALCIUM
FUEL	70.1	42.8	0.39	0.01
LIMESTONE	3.3	0.4	0.00	1.17
FLUIDIZING AIR	542.4			
TRANSPORT AIR	90.2			
PURGE AIR	15.5			
PROBE AIR	32.0			
RECYCLE AIR	0.0			
TOTAL IN	753.5	43.2	0.39	1.19
BED LETDOWN	0.0	0.0	0.00	0.00
CYCLONE HOPPER OVERFLOW	5.5	2.4	0.24	1.27
CYCLONE OUTLET DUST	0.5	0.1	0.02	0.06
FLUE GAS	747.4	40.7*	0.16	
TOTAL OUT	753.4	43.2	0.42	1.33
% ACCOUNTED FOR	100.0	100.0	108.5	111.9

* CO2 IN FLUE GAS CALCULATED BY DIFFERENCE

CHEMICAL ANALYSIS (WT. PERCENT)

FUEL TYPE	H2O*	C*	H	N	S*	O	ASH	BTU/LB
BENE. CWS	28.16	61.10	3.98	1.15	0.55	3.87	1.05	10890.

LIMESTONE TYPE	H2O	C(DRY%)	CAO(DRY%)	MGO(DRY%)	SO3(DRY%)	CO2(DRY%)
REED	0.20		50.10	0.70	0.00	40.80
BED LETDOWN	0.00	0.00	52.10		30.10	0.30
CYCLONE HOPPER OVERFLOW	0.30	34.80	32.40		11.00	34.80
CYCLONE OUTLET DUST	1.10	15.60	17.90		8.70	1.80

* C, S, AND H2O MEASURED FOR EACH TEST
H, N, O, ASH, AND BTU/LB BASED ON COMPOSITE OF ALL TESTS

```
TEST NUMBER =62.02      TEST DATE = 8/4/83       TEST TIME = 1330-1630

SUMMARY OF RESULTS

     SUPERFICIAL VELOCITY
        BASED ON AIR                            7.2  FT/SEC
        BASED ON FLUE GAS                       8.0  FT/SEC

     EXCESS AIR                                16.0  PCT

     CALCIUM/SULFUR RATIO                       2.4

     CARBON CONVERSION                         95.4  PCT

     COMBUSTION EFFICIENCY                     96.2  PCT

     SULFUR CAPTURE                            58.3  PCT
     (NORMALIZED)                              61.6  PCT

     CALCIUM UTILIZATION
        IN SPENT BED                           40.4  PCT
        IN CYCLONE ASH                         23.8  PCT
        IN BAGHOUSE ASH                        34.0  PCT


     O2 CONCENTRATION =     3.0  PCT
     SO2 CONCENTRATION(3% O2) =   203.   PPM          0.42  LB/MBTU
     NOX CONCENTRATION(3% O2) =   275.   PPM          0.37  LB/MBTU
     CO CONCENTRATION(3% O2) =    813.   PPM          0.66  LB/MBTU

     AVERAGE BED TEMPERATURE =        1565.  DEGREES F
     FREEBOARD #1 TEMPERATURE =       1607.  DEGREES F
     FREEBOARD #2 TEMPERATURE =       1644.  DEGREES F
     FREEBOARD #3 TEMPERATURE =       1546.  DEGREES F
     FREEBOARD #4 TEMPERATURE =       1069.  DEGREES F
     PREHEAT TEMPERATURE =             424.  DEGREES F

     FUEL FEED RATE =          70.1  LBS/HR
     LIMESTONE FEED RATE =      3.3  LBS/HR
     FINES RECYCLE RATE =       0.0  LBS/HR
     FINES RECYCLE RATIO =      0.0

     PLATE DP =                 4.9  IN H2O
     BED DP =                  23.2  IN H2O
     BED HEIGHT =              24.3  INCHES
```

TEST NUMBER =62.03   TEST DATE = 8/8/83   TEST TIME = 0830-1130

MATERIAL BALANCE (LBS/HR)

	TOTAL	CARBON	SULFUR	CALCIUM
FUEL	57.6	37.4	0.31	0.01
LIMESTONE	3.0	0.3	0.00	1.09
FLUIDIZING AIR	389.0			
TRANSPORT AIR	115.3			
PURGE AIR	18.3			
PROBE AIR	32.0			
RECYCLE AIR	0.0			
TOTAL IN	615.3	37.7	0.31	1.10
BED LETDOWN	0.0	0.0	0.00	0.00
CYCLONE HOPPER OVERFLOW	5.0	1.7	0.21	1.13
CYCLONE OUTLET DUST	0.5	0.1	0.02	0.06
FLUE GAS	610.8	36.0*	0.18	
TOTAL OUT	616.3	37.7	0.41	1.20
% ACCOUNTED FOR	100.2	100.0	133.0	109.1

* CO2 IN FLUE GAS CALCULATED BY DIFFERENCE

CHEMICAL ANALYSIS (WT. PERCENT)

FUEL TYPE	H2O*	C*	H	N	S*	O	ASH	BTU/LB
BENE. CWS	28.50	64.90	3.98	1.15	0.53	3.87	1.05	10890.

LIMESTONE TYPE	H2O	C(DRY%)	CAO(DRY%)	MGO(DRY%)	SO3(DRY%)	CO2(DRY%)
REED	0.20		50.10	0.70	0.00	40.80
BED LETDOWN	0.00	0.00	52.50		30.90	0.30
CYCLONE HOPPER OVERFLOW	0.40	32.40	31.90		10.40	3.30
CYCLONE OUTLET DUST	2.50	16.20	18.40		8.60	2.10

* C, S, AND H2O MEASURED FOR EACH TEST
H, N, O, ASH, AND BTU/LB BASED ON COMPOSITE OF ALL TESTS

```
TEST NUMBER =62.03        TEST DATE = 8/8/83        TEST TIME = 0830-1130


SUMMARY OF RESULTS

    SUPERFICIAL VELOCITY
       BASED ON AIR                                 5.9  FT/SEC
       BASED ON FLUE GAS                            6.6  FT/SEC

    EXCESS AIR                                     18.5  PCT

    CALCIUM/SULFUR RATIO                            2.9

    CARBON CONVERSION                              95.5  PCT

    COMBUSTION EFFICIENCY                          96.1  PCT

    SULFUR CAPTURE                                 40.4  PCT
    (NORMALIZED)                                   55.2  PCT

    CALCIUM UTILIZATION
       IN SPENT BED                                41.2  PCT
       IN CYCLONE ASH                              22.8  PCT
       IN BAGHOUSE ASH                             32.7  PCT


    O2 CONCENTRATION =      3.4  PCT
    SO2 CONCENTRATION(3% O2) =   281.   PPM            0.58  LB/MBTU
    NOX CONCENTRATION(3% O2) =   271.   PPM            0.36  LB/MBTU
    CO CONCENTRATION(3% O2) =    192.   PPM            0.16  LB/MBTU

    AVERAGE BED TEMPERATURE =        1557.   DEGREES F
    FREEBOARD #1 TEMPERATURE =       1594.   DEGREES F
    FREEBOARD #2 TEMPERATURE =       1623.   DEGREES F
    FREEBOARD #3 TEMPERATURE =       1513.   DEGREES F
    FREEBOARD #4 TEMPERATURE =        953.   DEGREES F
    PREHEAT TEMPERATURE =             419.   DEGREES F

    FUEL FEED RATE =          57.6  LBS/HR
    LIMESTONE FEED RATE =      3.0  LBS/HR
    FINES RECYCLE RATE =       0.0  LBS/HR
    FINES RECYCLE RATIO =      0.0

    PLATE DP =                 5.0  IN H2O
    BED DP =                  22.1  IN H2O
    BED HEIGHT =              24.8  INCHES
```

TEST NUMBER =62.04 TEST DATE = 8/8/83 TEST TIME = 1200-1500

MATERIAL BALANCE (LBS/HR)

	TOTAL	CARBON	SULFUR	CALCIUM
FUEL	54.5	33.2	0.29	0.01
LIMESTONE	2.5	0.3	0.00	0.91
FLUIDIZING AIR	362.6			
TRANSPORT AIR	91.5			
PURGE AIR	18.2			
PROBE AIR	31.8			
RECYCLE AIR	0.0			
TOTAL IN	561.2	33.5	0.29	0.92
BED LETDOWN	0.0	0.0	0.00	0.00
CYCLONE HOPPER OVERFLOW	2.7	0.7	0.11	0.89
CYCLONE OUTLET DUST	0.8	0.1	0.02	0.10
FLUE GAS	558.0	32.6*	0.38	
TOTAL OUT	561.4	33.5	0.52	0.98
% ACCOUNTED FOR	100.0	100.0	179.1	107.5

* CO_2 IN FLUE GAS CALCULATED BY DIFFERENCE

CHEMICAL ANALYSIS (WT. PERCENT)

FUEL TYPE	H_2O*	C*	H	N	S*	O	ASH	BTU/LB
BENE. CWS	28.40	60.90	3.98	1.15	0.53	3.87	1.05	10890.

LIMESTONE TYPE	H_2O	C(DRY%)	CAO(DRY%)	MGO(DRY%)	SO_3(DRY%)	CO_2(DRY%)
REED	0.20		50.10	0.70	0.00	40.80
BED LETDOWN	0.00	0.00	53.90		29.70	0.20
CYCLONE HOPPER OVERFLOW	0.30	27.00	46.20		10.40	2.40
CYCLONE OUTLET DUST	2.00	16.40	18.40		8.50	2.80

* C, S, AND H_2O MEASURED FOR EACH TEST
H, N, O, ASH, AND BTU/LB BASED ON COMPOSITE OF ALL TESTS

```
TEST NUMBER =62.04      TEST DATE = 8/8/83        TEST TIME = 1200-1500


SUMMARY OF RESULTS

     SUPERFICIAL VELOCITY
        BASED ON AIR                                5.6  FT/SEC
        BASED ON FLUE GAS                           6.3  FT/SEC

     EXCESS AIR                                    15.4  PCT

     CALCIUM/SULFUR RATIO                           2.5

     CARBON CONVERSION                             97.4  PCT

     COMBUSTION EFFICIENCY                         97.9  PCT

     SULFUR CAPTURE                               -31.7  PCT
     (NORMALIZED)                                  26.5  PCT

     CALCIUM UTILIZATION
        IN SPENT BED                               38.6  PCT
        IN CYCLONE ASH                             15.8  PCT
        IN BAGHOUSE ASH                            32.3  PCT


     O2 CONCENTRATION =       2.9   PCT
     SO2 CONCENTRATION(3% O2) =    643.   PPM            1.28  LB/MBTU
     NOX CONCENTRATION(3% O2) =    251.   PPM            0.32  LB/MBTU
     CO CONCENTRATION(3% O2) =     103.   PPM            0.08  LB/MBTU


     AVERAGE BED TEMPERATURE =         1653.   DEGREES F
     FREEBOARD #1 TEMPERATURE =        1687.   DEGREES F
     FREEBOARD #2 TEMPERATURE =        1707.   DEGREES F
     FREEBOARD #3 TEMPERATURE =        1590.   DEGREES F
     FREEBOARD #4 TEMPERATURE =         978.   DEGREES F
     PREHEAT TEMPERATURE =              458.   DEGREES F


     FUEL FEED RATE =           54.5  LBS/HR
     LIMESTONE FEED RATE =       2.5  LBS/HR
     FINES RECYCLE RATE =        0.0  LBS/HR
     FINES RECYCLE RATIO =       0.0


     PLATE DP =                  4.8  IN H2O
     BED DP =                   19.2  IN H2O
     BED HEIGHT =               23.3  INCHES
```

TEST NUMBER =62.05 TEST DATE = 8/9/83 TEST TIME = 0730-1030

MATERIAL BALANCE (LBS/HR)

	TOTAL	CARBON	SULFUR	CALCIUM
FUEL	51.5	31.4	0.29	0.01
LIMESTONE	2.8	0.3	0.00	1.00
FLUIDIZING AIR	350.2			
TRANSPORT AIR	92.5			
PURGE AIR	18.7			
PROBE AIR	32.2			
RECYCLE AIR	0.0			
TOTAL IN	547.8	31.7	0.29	1.00
BED LETDOWN	0.0	0.0	0.00	0.00
CYCLONE HOPPER OVERFLOW	4.3	1.3	0.15	0.91
CYCLONE OUTLET DUST	1.3	0.3	0.05	0.23
FLUE GAS	543.9	30.0*	0.87	
TOTAL OUT	549.5	31.7	1.07	1.14
% ACCOUNTED FOR	100.3	100.0	369.5	113.1

* CO2 IN FLUE GAS CALCULATED BY DIFFERENCE

CHEMICAL ANALYSIS (WT. PERCENT)

FUEL TYPE	H2O*	C*	H	N	S*	O	ASH	BTU/LB
BENE. CWS	28.40	60.90	3.98	1.15	0.56	3.87	1.05	10890.

LIMESTONE TYPE	H2O	C(DRY%)	CAO(DRY%)	MGO(DRY%)	SO3(DRY%)	CO2(DRY%)
REED	0.20		50.10	0.70	0.00	40.80
BED LETDOWN	0.00	0.10	56.20		25.60	0.20
CYCLONE HOPPER OVERFLOW	0.40	30.30	29.70		8.50	1.10
CYCLONE OUTLET DUST	0.90	24.40	24.80		10.60	1.80

* C, S, AND H2O MEASURED FOR EACH TEST
H, N, O, ASH, AND BTU/LB BASED ON COMPOSITE OF ALL TESTS

```
TEST NUMBER =62.05       TEST DATE = 8/9/83        TEST TIME = 0730-1030


SUMMARY OF RESULTS

     SUPERFICIAL VELOCITY
        BASED ON AIR                                   5.7  FT/SEC
        BASED ON FLUE GAS                              6.5  FT/SEC

     EXCESS AIR                                       16.6  PCT

     CALCIUM/SULFUR RATIO                              2.8

     CARBON CONVERSION                                94.9  PCT

     COMBUSTION EFFICIENCY                            95.8  PCT

     SULFUR CAPTURE                                 -200.0  PCT
     (NORMALIZED)                                     18.8  PCT

     CALCIUM UTILIZATION
        IN SPENT BED                                  31.9  PCT
        IN CYCLONE ASH                                20.0  PCT
        IN BAGHOUSE ASH                               29.9  PCT


     O2 CONCENTRATION =      3.1  PCT
     SO2 CONCENTRATION(3% O2) =  1501.  PPM            3.09  LB/MBTU
     NOX CONCENTRATION(3% O2) =   303.  PPM            0.40  LB/MBTU
     CO CONCENTRATION(3% O2) =    134.  PPM            0.11  LB/MBTU

     AVERAGE BED TEMPERATURE =        1748.  DEGREES F
     FREEBOARD #1 TEMPERATURE =       1731.  DEGREES F
     FREEBOARD #2 TEMPERATURE =       1685.  DEGREES F
     FREEBOARD #3 TEMPERATURE =       1299.  DEGREES F
     FREEBOARD #4 TEMPERATURE =        968.  DEGREES F
     PREHEAT TEMPERATURE =             408.  DEGREES F

     FUEL FEED RATE =         51.5  LBS/HR
     LIMESTONE FEED RATE =     2.8  LBS/HR
     FINES RECYCLE RATE =      0.0  LBS/HR
     FINES RECYCLE RATIO =     0.0

     PLATE DP =                6.1  IN H2O
     BED DP =                 19.9  IN H2O
     BED HEIGHT =             26.5  INCHES
```

TEST NUMBER =62.06 TEST DATE = 8/9/83 TEST TIME = 1100-1400

MATERIAL BALANCE (LBS/HR)

	TOTAL	CARBON	SULFUR	CALCIUM
FUEL	56.8	34.5	0.31	0.01
LIMESTONE	2.8	0.3	0.00	1.00
FLUIDIZING AIR	394.5			
TRANSPORT AIR	91.5			
PURGE AIR	18.0			
PROBE AIR	32.0			
RECYCLE AIR	0.0			
TOTAL IN	595.5	34.8	0.31	1.01
BED LETDOWN	0.0	0.0	0.00	0.00
CYCLONE HOPPER OVERFLOW	4.0	1.3	0.16	0.99
CYCLONE OUTLET DUST	0.9	0.2	0.03	0.13
FLUE GAS	591.5	33.3*	0.10	
TOTAL OUT	596.3	34.8	0.28	1.13
% ACCOUNTED FOR	100.1	100.0	89.9	112.0

* CO2 IN FLUE GAS CALCULATED BY DIFFERENCE

CHEMICAL ANALYSIS (WT. PERCENT)

FUEL TYPE	H2O*	C*	H	N	S*	O	ASH	BTU/LB
BENE. CWS	28.30	60.80	3.98	1.15	0.55	3.87	1.05	10890.

LIMESTONE TYPE	H2O	C(DRY%)	CAO(DRY%)	MGO(DRY%)	SO3(DRY%)	CO2(DRY%)
REED	0.20		50.10	0.70	0.00	40.80
BED LETDOWN	0.00	0.10	54.80		25.80	0.30
CYCLONE HOPPER OVERFLOW	0.10	32.70	34.80		9.90	2.20
CYCLONE OUTLET DUST	2.40	21.90	22.20		8.10	1.10

* C, S, AND H2O MEASURED FOR EACH TEST
H, N, O, ASH, AND BTU/LB BASED ON COMPOSITE OF ALL TESTS

```
TEST NUMBER =62.06      TEST DATE = 8/9/83        TEST TIME = 1100-1400


SUMMARY OF RESULTS

     SUPERFICIAL VELOCITY
        BASED ON AIR                           5.7  FT/SEC
        BASED ON FLUE GAS                      6.4  FT/SEC

     EXCESS AIR                               16.0  PCT

     CALCIUM/SULFUR RATIO                      2.6

     CARBON CONVERSION                        95.7  PCT

     COMBUSTION EFFICIENCY                    96.5  PCT

     SULFUR CAPTURE                           69.5  PCT
     (NORMALIZED)                             66.1  PCT

     CALCIUM UTILIZATION
        IN SPENT BED                          33.0  PCT
        IN CYCLONE ASH                        19.9  PCT
        IN BAGHOUSE ASH                       25.5  PCT


     O2 CONCENTRATION =      3.0  PCT
     SO2 CONCENTRATION(3% O2) =   152.   PPM          0.31  LB/MBTU
     NOX CONCENTRATION(3% O2) =   255.   PPM          0.33  LB/MBTU
     CO CONCENTRATION(3% O2) =    409.   PPM          0.33  LB/MBTU

     AVERAGE BED TEMPERATURE =        1559.   DEGREES F
     FREEBOARD #1 TEMPERATURE =       1625.   DEGREES F
     FREEBOARD #2 TEMPERATURE =       1671.   DEGREES F
     FREEBOARD #3 TEMPERATURE =       1558.   DEGREES F
     FREEBOARD #4 TEMPERATURE =        997.   DEGREES F
     PREHEAT TEMPERATURE =             423.   DEGREES F

     FUEL FEED RATE =          56.8  LBS/HR
     LIMESTONE FEED RATE =      2.8  LBS/HR
     FINES RECYCLE RATE =       0.0  LBS/HR
     FINES RECYCLE RATIO =      0.0

     PLATE DP =                 6.2  IN H2O
     BED DP =                  17.7  IN H2O
     BED HEIGHT =              24.3  INCHES
```

TEST NUMBER =62.07 TEST DATE = 8/10/83 TEST TIME = 0730-1030

MATERIAL BALANCE (LBS/HR)

	TOTAL	CARBON	SULFUR	CALCIUM
FUEL	42.0	25.5	0.23	0.01
LIMESTONE	2.0	0.2	0.00	0.71
FLUIDIZING AIR	243.9			
TRANSPORT AIR	91.3			
PURGE AIR	18.6			
PROBE AIR	32.5			
RECYCLE AIR	0.0			
TOTAL IN	430.3	25.8	0.23	0.72
BED LETDOWN	0.0	0.0	0.00	0.00
CYCLONE HOPPER OVERFLOW	4.0	1.6	0.12	0.74
CYCLONE OUTLET DUST	0.7	0.1	0.02	0.09
FLUE GAS	426.7	24.0*	0.10	
TOTAL OUT	431.4	25.8	0.25	0.83
% ACCOUNTED FOR	100.2	100.0	108.1	114.9

* CO_2 IN FLUE GAS CALCULATED BY DIFFERENCE

CHEMICAL ANALYSIS (WT. PERCENT)

FUEL TYPE	H_2O*	C*	H	N	S*	O	ASH	BTU/LB
BENE. CWS	28.30	60.80	3.98	1.15	0.54	3.87	1.05	10890.

LIMESTONE TYPE	H_2O	C(DRY%)	CAO(DRY%)	MGO(DRY%)	SO_3(DRY%)	CO_2(DRY%)
REED	0.20		50.10	0.70	0.00	40.80
BED LETDOWN	0.00	0.00	54.80		28.10	0.20
CYCLONE HOPPER OVERFLOW	1.80	40.70	26.30		7.50	2.60
CYCLONE OUTLET DUST	1.20	19.20	19.20		8.50	1.30

* C, S, AND H_2O MEASURED FOR EACH TEST
H, N, O, ASH, AND BTU/LB BASED ON COMPOSITE OF ALL TESTS

```
TEST NUMBER =62.07      TEST DATE = 8/10/83       TEST TIME = 0730-1030


SUMMARY OF RESULTS

     SUPERFICIAL VELOCITY
        BASED ON AIR                              4.1  FT/SEC
        BASED ON FLUE GAS                         4.6  FT/SEC

     EXCESS AIR                                  16.0  PCT

     CALCIUM/SULFUR RATIO                         2.5

     CARBON CONVERSION                           93.2  PCT

     COMBUSTION EFFICIENCY                       94.5  PCT

     SULFUR CAPTURE                              53.8  PCT
     (NORMALIZED)                                57.2  PCT

     CALCIUM UTILIZATION
        IN SPENT BED                             35.9  PCT
        IN CYCLONE ASH                           20.0  PCT
        IN BAGHOUSE ASH                          31.0  PCT


     O2 CONCENTRATION =      3.0  PCT
     SO2 CONCENTRATION(3% O2) =   232.   PPM           0.46  LB/MBTU
     NOX CONCENTRATION(3% O2) =   228.   PPM           0.29  LB/MBTU
     CO CONCENTRATION(3% O2) =    126.   PPM           0.10  LB/MBTU


     AVERAGE BED TEMPERATURE =        1557.   DEGREES F
     FREEBOARD #1 TEMPERATURE =       1587.   DEGREES F
     FREEBOARD #2 TEMPERATURE =       1621.   DEGREES F
     FREEBOARD #3 TEMPERATURE =       1490.   DEGREES F
     FREEBOARD #4 TEMPERATURE =        898.   DEGREES F
     PREHEAT TEMPERATURE =             406.   DEGREES F


     FUEL FEED RATE =           42.0  LBS/HR
     LIMESTONE FEED RATE =       2.0  LBS/HR
     FINES RECYCLE RATE =        0.0  LBS/HR
     FINES RECYCLE RATIO =       0.0


     PLATE DP =                  4.7  IN H2O
     BED DP =                   23.3  IN H2O
     BED HEIGHT =               25.0  INCHES
```

TEST NUMBER =62.08 TEST DATE = 8/10/83 TEST TIME = 1130-1430

MATERIAL BALANCE (LBS/HR)

	TOTAL	CARBON	SULFUR	CALCIUM
FUEL	33.6	20.3	0.17	0.01
LIMESTONE	1.0	0.1	0.00	0.36
FLUIDIZING AIR	161.9			
TRANSPORT AIR	86.2			
PURGE AIR	18.4			
PROBE AIR	32.1			
RECYCLE AIR	0.0			
TOTAL IN	333.2	20.4	0.17	0.37
BED LETDOWN	0.0	0.0	0.00	0.00
CYCLONE HOPPER OVERFLOW	2.0	0.6	0.06	0.35
CYCLONE OUTLET DUST	0.5	0.1	0.02	0.08
FLUE GAS	331.4	19.7*	0.08	
TOTAL OUT	333.9	20.4	0.16	0.43
% ACCOUNTED FOR	100.2	100.0	92.4	117.3

* CO2 IN FLUE GAS CALCULATED BY DIFFERENCE

CHEMICAL ANALYSIS (WT. PERCENT)

FUEL TYPE	H2O*	C*	H	N	S*	O	ASH	BTU/LB
BENE. CWS	28.20	60.40	3.98	1.15	0.51	3.87	1.05	10890.

LIMESTONE TYPE	H2O	C(DRY%)	CAO(DRY%)	MGO(DRY%)	SO3(DRY%)	CO2(DRY%)
REED	0.20		50.10	0.70	0.00	40.80
BED LETDOWN	0.00	0.10	54.80		27.30	0.20
CYCLONE HOPPER OVERFLOW	9.70	31.90	27.30		8.10	4.60
CYCLONE OUTLET DUST	1.90	18.40	22.10		9.00	1.80

* C, S, AND H2O MEASURED FOR EACH TEST
H, N, O, ASH, AND BTU/LB BASED ON COMPOSITE OF ALL TESTS

```
TEST NUMBER =62.08      TEST DATE = 8/10/83       TEST TIME = 1130-1430


SUMMARY OF RESULTS

     SUPERFICIAL VELOCITY
        BASED ON AIR                                   3.1  FT/SEC
        BASED ON FLUE GAS                              3.6  FT/SEC

     EXCESS AIR                                       16.0  PCT

     CALCIUM/SULFUR RATIO                              1.7

     CARBON CONVERSION                                96.7  PCT

     COMBUSTION EFFICIENCY                            97.4  PCT

     SULFUR CAPTURE                                   52.1  PCT
     (NORMALIZED)                                     48.1  PCT

     CALCIUM UTILIZATION
        IN SPENT BED                                  34.9  PCT
        IN CYCLONE ASH                                20.8  PCT
        IN BAGHOUSE ASH                               28.5  PCT


     O2 CONCENTRATION =     3.0  PCT
     SO2 CONCENTRATION(3% O2) =    234.  PPM             0.45  LB/MBTU
     NOX CONCENTRATION(3% O2) =    236.  PPM             0.29  LB/MBTU
     CO CONCENTRATION(3% O2) =     116.  PPM             0.09  LB/MBTU

     AVERAGE BED TEMPERATURE =        1528.  DEGREES F
     FREEBOARD #1 TEMPERATURE =       1659.  DEGREES F
     FREEBOARD #2 TEMPERATURE =       1651.  DEGREES F
     FREEBOARD #3 TEMPERATURE =       1491.  DEGREES F
     FREEBOARD #4 TEMPERATURE =        900.  DEGREES F
     PREHEAT TEMPERATURE =             451.  DEGREES F

     FUEL FEED RATE =          33.6  LBS/HR
     LIMESTONE FEED RATE =      1.0  LBS/HR
     FINES RECYCLE RATE =       0.0  LBS/HR
     FINES RECYCLE RATIO =      0.0

     PLATE DP =                 4.8  IN H2O
     BED DP =                  20.2  IN H2O
     BED HEIGHT =              22.3  INCHES
```

TEST NUMBER =62.09 TEST DATE = 8/11/83 TEST TIME = 0700-1000

MATERIAL BALANCE (LBS/HR)

	TOTAL	CARBON	SULFUR	CALCIUM
FUEL	57.1	34.8	0.29	0.01
LIMESTONE	1.3	0.1	0.00	0.45
FLUIDIZING AIR	376.3			
TRANSPORT AIR	93.8			
PURGE AIR	18.5			
PROBE AIR	32.3			
RECYCLE AIR	36.9			
TOTAL IN	616.2	35.0	0.29	0.46
BED LETDOWN	0.0	0.0	0.00	0.00
CYCLONE HOPPER OVERFLOW	2.0	0.6	0.07	0.37
CYCLONE OUTLET DUST	1.1	0.2	0.04	0.16
FLUE GAS	613.8	34.2*	0.10	
TOTAL OUT	616.9	35.0	0.20	0.52
% ACCOUNTED FOR	100.1	100.0	70.2	114.2

* CO2 IN FLUE GAS CALCULATED BY DIFFERENCE

CHEMICAL ANALYSIS (WT. PERCENT)

FUEL TYPE	H2O*	C*	H	N	S*	O	ASH	BTU/LB
BENE. CWS	28.20	61.00	3.98	1.15	0.51	3.87	1.05	10890

LIMESTONE TYPE	H2O	C(DRY%)	CAO(DRY%)	MGO(DRY%)	SO3(DRY%)	CO2(DRY%)
REED	0.20		50.10	0.70	0.00	40.80
BED LETDOWN	0.00	0.10	53.90		28.80	0.30
CYCLONE HOPPER OVERFLOW	1.90	29.10	26.30		8.70	4.40
CYCLONE OUTLET DUST	0.50	20.00	20.00		8.70	1.50

* C, S, AND H2O MEASURED FOR EACH TEST
  H, N, O, ASH, AND BTU/LB BASED ON COMPOSITE OF ALL TESTS

```
TEST NUMBER =62.09      TEST DATE = 8/11/83      TEST TIME = 0700-1000

SUMMARY OF RESULTS

     SUPERFICIAL VELOCITY
        BASED ON AIR                                   5.9  FT/SEC
        BASED ON FLUE GAS                              6.7  FT/SEC

     EXCESS AIR                                       17.3  PCT

     CALCIUM/SULFUR RATIO                              1.2

     CARBON CONVERSION                                97.7  PCT

     COMBUSTION EFFICIENCY                            98.2  PCT

     SULFUR CAPTURE                                   66.3  PCT
     (NORMALIZED)                                     52.0  PCT

     CALCIUM UTILIZATION
        IN SPENT BED                                  37.4  PCT
        IN CYCLONE ASH                                23.2  PCT
        IN BAGHOUSE ASH                               30.4  PCT


     O2 CONCENTRATION =     3.2  PCT
     SO2 CONCENTRATION(3% O2) =   151.   PPM           0.32  LB/MBTU
     NOX CONCENTRATION(3% O2) =   237.   PPM           0.32  LB/MBTU
     CO CONCENTRATION(3% O2) =    526.   PPM           0.43  LB/MBTU

     AVERAGE BED TEMPERATURE =        1563.  DEGREES F
     FREEBOARD #1 TEMPERATURE =       1585.  DEGREES F
     FREEBOARD #2 TEMPERATURE =       1571.  DEGREES F
     FREEBOARD #3 TEMPERATURE =       1460.  DEGREES F
     FREEBOARD #4 TEMPERATURE =        986.  DEGREES F
     PREHEAT TEMPERATURE =             407.  DEGREES F

     FUEL FEED RATE =          57.1  LBS/HR
     LIMESTONE FEED RATE =      1.3  LBS/HR
     FINES RECYCLE RATE =      58.0  LBS/HR
     FINES RECYCLE RATIO =      1.0

     PLATE DP =                 4.4  IN H2O
     BED DP =                  19.2  IN H2O
     BED HEIGHT =              22.8  INCHES
```

TEST NUMBER =62.10   TEST DATE = 8/11/83   TEST TIME = 1030-1330

MATERIAL BALANCE (LBS/HR)

	TOTAL	CARBON	SULFUR	CALCIUM
FUEL	57.1	34.8	0.28	0.01
LIMESTONE	1.0	0.1	0.00	0.36
FLUIDIZING AIR	395.8			
TRANSPORT AIR	92.5			
PURGE AIR	18.4			
PROBE AIR	32.2			
RECYCLE AIR	0.0			
TOTAL IN	596.9	34.9	0.28	0.37
BED LETDOWN	0.0	0.0	0.00	0.00
CYCLONE HOPPER OVERFLOW	2.5	1.2	0.06	0.25
CYCLONE OUTLET DUST	0.6	0.1	0.02	0.09
FLUE GAS	594.4	33.6*	0.15	
TOTAL OUT	597.5	34.9	0.23	0.35
% ACCOUNTED FOR	100.1	100.0	82.5	95.0

* CO2 IN FLUE GAS CALCULATED BY DIFFERENCE

CHEMICAL ANALYSIS (WT. PERCENT)

FUEL TYPE	H2O*	C*	H	N	S*	O	ASH	BTU/LB
BENE CWB	29.00	61.00	3.98	1.15	0.49	3.87	1.05	10890.

LIMESTONE TYPE	H2O	C(DRY%)	CAO(DRY%)	MGO(DRY%)	SO3(DRY%)	CO2(DRY%)
REED	0.20		50.10	0.70	0.00	40.80
BED LETDOWN	0.00	0.00	53.90		28.60	0.20
CYCLONE HOPPER OVERFLOW	2.40	49.60	14.60		6.20	1.30
CYCLONE OUTLET DUST	1.10	19.70	23.30		7.90	1.20

* C, S, AND H2O MEASURED FOR EACH TEST
H, N, O, ASH, AND BTU/LB BASED ON COMPOSITE OF ALL TESTS

```
TEST NUMBER =62.10      TEST DATE = 8/11/83       TEST TIME = 1030-1330


SUMMARY OF RESULTS

     SUPERFICIAL VELOCITY
        BASED ON AIR                             5.7  FT/SEC
        BASED ON FLUE GAS                        6.5  FT/SEC

     EXCESS AIR                                 16.0  PCT

     CALCIUM/SULFUR RATIO                        1.0

     CARBON CONVERSION                          96.2  PCT

     COMBUSTION EFFICIENCY                      96.9  PCT

     SULFUR CAPTURE                             45.5  PCT
     (NORMALIZED)                               33.9  PCT

     CALCIUM UTILIZATION
        IN SPENT BED                            37.1  PCT
        IN CYCLONE ASH                          29.7  PCT
        IN BAGHOUSE ASH                         23.7  PCT


     O2 CONCENTRATION =    3.0  PCT
     SO2 CONCENTRATION(3% O2) =    242.   PPM            0.49  LB/MBTU
     NOX CONCENTRATION(3% O2) =    254.   PPM            0.33  LB/MBTU
     CO CONCENTRATION(3% O2) =     237.   PPM            0.19  LB/MBTU

     AVERAGE BED TEMPERATURE =       1561.   DEGREES F
     FREEBOARD #1 TEMPERATURE =      1624.   DEGREES F
     FREEBOARD #2 TEMPERATURE =      1661.   DEGREES F
     FREEBOARD #3 TEMPERATURE =      1548.   DEGREES F
     FREEBOARD #4 TEMPERATURE =       984.   DEGREES F
     PREHEAT TEMPERATURE =            400.   DEGREES F

     FUEL FEED RATE =          57.1  LBS/HR
     LIMESTONE FEED RATE =      1.0  LBS/HR
     FINES RECYCLE RATE =       0.0  LBS/HR
     FINES RECYCLE RATIO =      0.0

     PLATE DP =                 4.3  IN H2O
     BED DP =                  19.5  IN H2O
     BED HEIGHT =              22.8  INCHES
```

TEST SERIES 63 -- SCOTIA-LIQUICOAL UNBENEFICIATED CWS

TEST NUMBER =63.01 TEST DATE = 9/9/83 TEST TIME = 1100-1400

MATERIAL BALANCE (LBS/HR)

	TOTAL	CARBON	SULFUR	CALCIUM
FUEL	86.0	34.5	2.94	0.35
LIMESTONE	30.0	3.3	0.00	10.79
FLUIDIZING AIR	397.9			
TRANSPORT AIR	101.5			
PURGE AIR	17.6			
PROBE AIR	31.9			
RECYCLE AIR	0.0			
TOTAL IN	665.0	37.8	2.94	11.14
BED LETDOWN	25.0	0.0	2.77	9.89
CYCLONE HOPPER OVERFLOW	13.3	2.9	0.37	1.98
CYCLONE OUTLET DUST	0.5	0.1	0.02	0.07
FLUE GAS	636.3	34.8*	0.50	
TOTAL OUT	675.0	37.8	3.67	11.95
% ACCOUNTED FOR	101.5	100.0	124.8	107.3

* CO2 IN FLUE GAS CALCULATED BY DIFFERENCE

CHEMICAL ANALYSIS (WT. PERCENT)

FUEL TYPE	H2O*	C*	H	N	S*	O	ASH	BTU/LB
UNBEN. CWS	41.00	40.06	2.51	0.62	3.42	3.82	8.73	6970.

LIMESTONE TYPE	H2O	C(DRY%)	CAO(DRY%)	MGO(DRY%)	SO3(DRY%)	CO2(DRY%)
REED	0.10		50.40	0.48	0.00	40.70
BED LETDOWN	0.00	0.07	55.40		27.74	0.33
CYCLONE HOPPER OVERFLOW	0.70	20.50	21.00		7.06	3.96
CYCLONE OUTLET DUST	0.40	10.50	21.00		10.74	1.42

* C, S, AND H2O MEASURED FOR EACH TEST
H, N, O, ASH, AND BTU/LB BASED ON COMPOSITE OF ALL TESTS

```
TEST NUMBER =63.01      TEST DATE = 9/9/83        TEST TIME = 1100-1400


SUMMARY OF RESULTS

     SUPERFICIAL VELOCITY
        BASED ON AIR                               5.8  FT/SEC
        BASED ON FLUE GAS                          6.7  FT/SEC

     EXCESS AIR                                   14.8  PCT

     CALCIUM/SULFUR RATIO                          2.9

     CARBON CONVERSION                            91.9  PCT

     COMBUSTION EFFICIENCY                        93.3  PCT

     SULFUR CAPTURE                               82.9  PCT
     (NORMALIZED)                                 86.3  PCT

     CALCIUM UTILIZATION
        IN SPENT BED                              35.1  PCT
        IN CYCLONE ASH                            23.5  PCT
        IN BAGHOUSE ASH                           35.8  PCT


     O2 CONCENTRATION =      2.8  PCT
     SO2 CONCENTRATION(3% O2) =   747.   PPM            1.68  LB/MBTU
     NOX CONCENTRATION(3% O2) =   116.   PPM            0.16  LB/MBTU
     CO CONCENTRATION(3% O2) =   1435.   PPM            1.21  LB/MBTU


     AVERAGE BED TEMPERATURE =         1549.   DEGREES F
     FREEBOARD #1 TEMPERATURE =        1572.   DEGREES F
     FREEBOARD #2 TEMPERATURE =        1574.   DEGREES F
     FREEBOARD #3 TEMPERATURE =        1462.   DEGREES F
     FREEBOARD #4 TEMPERATURE =        1002.   DEGREES F
     PREHEAT TEMPERATURE =              471.   DEGREES F


     FUEL FEED RATE =          86.0  LBS/HR
     LIMESTONE FEED RATE =     30.0  LBS/HR
     FINES RECYCLE RATE =       0.0  LBS/HR
     FINES RECYCLE RATIO =      0.0


     PLATE DP =                 6.1  IN H2O
     BED DP =                  20.5  IN H2O
     BED HEIGHT =              27.5  INCHES
```

TEST NUMBER =63.02 TEST DATE = 9/12/83 TEST TIME = 0900-1145

MATERIAL BALANCE (LBS/HR)

	TOTAL	CARBON	SULFUR	CALCIUM
FUEL	62.5	24.7	2.21	0.25
LIMESTONE	22.5	2.5	0.00	8.09
FLUIDIZING AIR	287.8			
TRANSPORT AIR	103.4			
PURGE AIR	17.0			
PROBE AIR	30.2			
RECYCLE AIR	0.0			
TOTAL IN	523.4	27.2	2.21	8.34
BED LETDOWN	13.3	0.0	1.53	5.13
CYCLONE HOPPER OVERFLOW	12.5	1.3	0.50	3.77
CYCLONE OUTLET DUST	1.5	0.1	0.06	0.22
FLUE GAS	502.6	25.7*	0.29	
TOTAL OUT	529.9	27.2	2.38	9.12
% ACCOUNTED FOR	101.2	100.0	107.8	109.3

* CO_2 IN FLUE GAS CALCULATED BY DIFFERENCE

CHEMICAL ANALYSIS (WT. PERCENT)

FUEL TYPE	H_2O*	C*	H	N	S*	O	ASH	BTU/LB
UNBEN. CWS	41.10	39.47	2.51	0.62	3.53	3.82	8.73	6970.

LIMESTONE TYPE	H_2O	C(DRY%)	CAO(DRY%)	MGO(DRY%)	SO_3(DRY%)	CO_2(DRY%)
REED	0.10		50.40	0.48	0.00	40.70
BED LETDOWN	0.00	0.03	54.00		28.73	0.19
CYCLONE HOPPER OVERFLOW	0.30	9.00	42.30		10.03	6.28
CYCLONE OUTLET DUST	2.40	8.00	21.20		10.82	1.45

* C, S, AND H_2O MEASURED FOR EACH TEST
H, N, O, ASH, AND BTU/LB BASED ON COMPOSITE OF ALL TESTS

```
TEST NUMBER =63.02       TEST DATE = 9/12/83       TEST TIME = 0900-1145

SUMMARY OF RESULTS

     SUPERFICIAL VELOCITY
        BASED ON AIR                                 4.6  FT/SEC
        BASED ON FLUE GAS                            5.5  FT/SEC

     EXCESS AIR                                     16.6  PCT

     CALCIUM/SULFUR RATIO                            2.9

     CARBON CONVERSION                              95.0  PCT

     COMBUSTION EFFICIENCY                          95.9  PCT

     SULFUR CAPTURE                                 87.0  PCT
     (NORMALIZED)                                   87.9  PCT

     CALCIUM UTILIZATION
        IN SPENT BED                                37.2  PCT
        IN CYCLONE ASH                              16.6  PCT
        IN BAGHOUSE ASH                             35.7  PCT


     O2 CONCENTRATION =     3.1  PCT
     SO2 CONCENTRATION(3% O2) =    539.   PPM           1.32  LB/MBTU
     NOX CONCENTRATION(3% O2) =    145.   PPM           0.22  LB/MBTU
     CO CONCENTRATION(3% O2) =     337.   PPM           0.31  LB/MBTU

     AVERAGE BED TEMPERATURE =         1557.   DEGREES F
     FREEBOARD #1 TEMPERATURE =        1578.   DEGREES F
     FREEBOARD #2 TEMPERATURE =        1581.   DEGREES F
     FREEBOARD #3 TEMPERATURE =        1474.   DEGREES F
     FREEBOARD #4 TEMPERATURE =         904.   DEGREES F
     PREHEAT TEMPERATURE =              475.   DEGREES F

     FUEL FEED RATE =            62.5  LBS/HR
     LIMESTONE FEED RATE =       22.5  LBS/HR
     FINES RECYCLE RATE =         0.0  LBS/HR
     FINES RECYCLE RATIO =        0.0

     PLATE DP =                   5.3  IN H2O
     BED DP =                    24.7  IN H2O
     BED HEIGHT =                26.0  INCHES
```

TEST NUMBER =63.03 TEST DATE = 9/12/83 TEST TIME = 1230-1530

MATERIAL BALANCE (LBS/HR)

	TOTAL	CARBON	SULFUR	CALCIUM
FUEL	103.9	41.5	3.50	0.42
LIMESTONE	37.0	4.1	0.00	13.31
FLUIDIZING AIR	500.2			
TRANSPORT AIR	101.7			
PURGE AIR	16.9			
PROBE AIR	30.0			
RECYCLE AIR	0.0			
TOTAL IN	789.8	45.6	3.50	13.73
BED LETDOWN	20.3	0.0	2.38	8.03
CYCLONE HOPPER OVERFLOW	23.3	3.3	1.18	6.83
CYCLONE OUTLET DUST	1.6	0.1	0.08	0.25
FLUE GAS	750.6	42.2*	0.84	
TOTAL OUT	795.8	45.6	4.47	15.11
% ACCOUNTED FOR	100.8	100.0	127.7	110.1

* CO2 IN FLUE GAS CALCULATED BY DIFFERENCE

CHEMICAL ANALYSIS (WT. PERCENT)

FUEL TYPE	H2O*	C*	H	N	S*	O	ASH	BTU/LB
UNBEN. CWS	40.30	39.94	2.51	0.62	3.37	3.82	8.73	6970.

LIMESTONE TYPE	H2O	C(DRY%)	CAO(DRY%)	MGO(DRY%)	SO3(DRY%)	CO2(DRY%)
REED	0.10		50.40	0.48	0.00	40.70
BED LETDOWN	0.00	0.02	55.40		29.33	0.17
CYCLONE HOPPER OVERFLOW	0.20	12.40	41.10		12.65	6.59
CYCLONE OUTLET DUST	0.50	8.20	21.80		11.96	1.64

* C, S, AND H2O MEASURED FOR EACH TEST
H, N, O, ASH, AND BTU/LB BASED ON COMPOSITE OF ALL TESTS

```
TEST NUMBER =63.03        TEST DATE = 9/12/83        TEST TIME = 1230-1530

SUMMARY OF RESULTS

     SUPERFICIAL VELOCITY
        BASED ON AIR                                   6.8  FT/SEC
        BASED ON FLUE GAS                              8.0  FT/SEC

     EXCESS AIR                                       15.4  PCT

     CALCIUM/SULFUR RATIO                              3.0

     CARBON CONVERSION                                92.7  PCT

     COMBUSTION EFFICIENCY                            94.0  PCT

     SULFUR CAPTURE                                   76.1  PCT
     (NORMALIZED)                                     81.3  PCT

     CALCIUM UTILIZATION
        IN SPENT BED                                  37.1  PCT
        IN CYCLONE ASH                                21.5  PCT
        IN BAGHOUSE ASH                               38.4  PCT


     O2 CONCENTRATION =     2.9  PCT
     SO2 CONCENTRATION(3% O2) =  1051.  PPM           2.31  LB/MBTU
     NOX CONCENTRATION(3% O2) =   154.  PPM           0.21  LB/MBTU
     CO CONCENTRATION(3% O2) =   1701.  PPM           1.40  LB/MBTU

     AVERAGE BED TEMPERATURE =        1551.  DEGREES F
     FREEBOARD #1 TEMPERATURE =       1592.  DEGREES F
     FREEBOARD #2 TEMPERATURE =       1611.  DEGREES F
     FREEBOARD #3 TEMPERATURE =       1530.  DEGREES F
     FREEBOARD #4 TEMPERATURE =       1093.  DEGREES F
     PREHEAT TEMPERATURE =             393.  DEGREES F

     FUEL FEED RATE =          103.9  LBS/HR
     LIMESTONE FEED RATE =      37.0  LBS/HR
     FINES RECYCLE RATE =        0.0  LBS/HR
     FINES RECYCLE RATIO =       0.0

     PLATE DP =                  6.5  IN H2O
     BED DP =                   20.5  IN H2O
     BED HEIGHT =               28.8  INCHES
```

TEST NUMBER =63.04   TEST DATE = 9/13/83   TEST TIME = 0730-1030

MATERIAL BALANCE (LBS/HR)

	TOTAL	CARBON	SULFUR	CALCIUM
FUEL	85.2	33.8	2.88	0.34
LIMESTONE	49.0	5.4	0.00	17.62
FLUIDIZING AIR	393.8			
TRANSPORT AIR	98.1			
PURGE AIR	17.6			
PROBE AIR	32.4			
RECYCLE AIR	0.0			
TOTAL IN	676.1	39.2	2.88	17.97
BED LETDOWN	31.3	0.0	3.28	12.79
CYCLONE HOPPER OVERFLOW	19.3	3.1	0.65	3.31
CYCLONE OUTLET DUST	0.9	0.1	0.05	0.15
FLUE GAS	632.1	36.0*	0.25	
TOTAL OUT	683.6	39.2	4.23	16.24
% ACCOUNTED FOR	101.1	100.0	146.7	90.4

* CO2 IN FLUE GAS CALCULATED BY DIFFERENCE

CHEMICAL ANALYSIS (WT. PERCENT)

FUEL TYPE	H2O*	C*	H	N	S*	O	ASH	BTU/LB
UNBEN. CWS	40.10	39.62	2.51	0.62	3.38	3.82	8.73	6970.

LIMESTONE TYPE	H2O	C(DRY%)	CAO(DRY%)	MGO(DRY%)	SO3(DRY%)	CO2(DRY%)
REED	0.10		50.40	0.48	0.00	40.70
BED LETDOWN	0.00	0.03	57.20		26.16	0.35
CYCLONE HOPPER OVERFLOW	0.90	14.80	24.20		8.46	4.55
CYCLONE OUTLET DUST	1.20	7.20	23.50		14.45	2.45

* C, S, AND H2O MEASURED FOR EACH TEST
H, N, O, ASH, AND BTU/LB BASED ON COMPOSITE OF ALL TESTS

```
TEST NUMBER =63.04      TEST DATE = 9/13/83       TEST TIME = 0730-1030


SUMMARY OF RESULTS

     SUPERFICIAL VELOCITY
        BASED ON AIR                              5.7  FT/SEC
        BASED ON FLUE GAS                         6.8  FT/SEC

     EXCESS AIR                                  16.6  PCT

     CALCIUM/SULFUR RATIO                         4.9

     CARBON CONVERSION                           91.4  PCT

     COMBUSTION EFFICIENCY                       92.9  PCT

     SULFUR CAPTURE                              91.3  PCT
     (NORMALIZED)                                94.1  PCT

     CALCIUM UTILIZATION
        IN SPENT BED                             32.0  PCT
        IN CYCLONE ASH                           24.5  PCT
        IN BAGHOUSE ASH                          43.0  PCT


     O2 CONCENTRATION =     3.1  PCT
     SO2 CONCENTRATION(3% O2) =   375.   PPM            0.85  LB/MBTU
     NOX CONCENTRATION(3% O2) =   137.   PPM            0.19  LB/MBTU
     CO CONCENTRATION(3% O2) =   1412.   PPM            1.20  LB/MBTU


     AVERAGE BED TEMPERATURE =        1562.  DEGREES F
     FREEBOARD #1 TEMPERATURE =       1588.  DEGREES F
     FREEBOARD #2 TEMPERATURE =       1587.  DEGREES F
     FREEBOARD #3 TEMPERATURE =       1479.  DEGREES F
     FREEBOARD #4 TEMPERATURE =       1002.  DEGREES F
     PREHEAT TEMPERATURE =             406.  DEGREES F


     FUEL FEED RATE =         85.2  LBS/HR
     LIMESTONE FEED RATE =    49.0  LBS/HR
     FINES RECYCLE RATE =      0.0  LBS/HR
     FINES RECYCLE RATIO =     0.0


     PLATE DP =                4.6  IN H2O
     BED DP =                 22.8  IN H2O
     BED HEIGHT =             28.8  INCHES
```

TEST NUMBER =63.05 TEST DATE = 9/14/83 TEST TIME = 0500-0800

MATERIAL BALANCE (LBS/HR)

	TOTAL	CARBON	SULFUR	CALCIUM
FUEL	81.0	33.0	2.75	0.33
LIMESTONE	28.0	3.1	0.00	10.07
FLUIDIZING AIR	371.6			
TRANSPORT AIR	98.3			
PURGE AIR	16.5			
PROBE AIR	32.2			
RECYCLE AIR	0.0			
TOTAL IN	627.6	36.1	2.75	10.40
BED LETDOWN	20.6	0.0	2.37	8.18
CYCLONE HOPPER OVERFLOW	14.5	3.0	0.49	3.12
CYCLONE OUTLET DUST	2.2	0.2	0.11	0.34
FLUE GAS	596.2	32.9*	0.72	
TOTAL OUT	633.5	36.1	3.67	11.64
% ACCOUNTED FOR	100.9	100.0	133.8	112.0

* CO2 IN FLUE GAS CALCULATED BY DIFFERENCE

CHEMICAL ANALYSIS (WT. PERCENT)

FUEL TYPE	H2O*	C*	H	N	S*	O	ASH	BTU/LB
UNBEN. CWS	38.90	40.74	2.51	0.62	3.39	3.82	8.73	6970.

LIMESTONE TYPE	H2O	C(DRY%)	CAO(DRY%)	MGO(DRY%)	SO3(DRY%)	CO2(DRY%)
REED	0.10		50.40	0.48	0.00	40.70
BED LETDOWN	0.00	0.03	55.60		28.72	0.16
CYCLONE HOPPER OVERFLOW	0.60	19.80	30.30		8.45	4.32
CYCLONE OUTLET DUST	1.80	8.20	22.00		12.24	1.85

* C, S, AND H2O MEASURED FOR EACH TEST
H, N, O, ASH, AND BTU/LB BASED ON COMPOSITE OF ALL TESTS

```
TEST NUMBER =63.05      TEST DATE = 9/14/83       TEST TIME = 0500-0800


SUMMARY OF RESULTS

     SUPERFICIAL VELOCITY
        BASED ON AIR                           5.7  FT/SEC
        BASED ON FLUE GAS                      6.7  FT/SEC

     EXCESS AIR                               16.0  PCT

     CALCIUM/SULFUR RATIO                      2.9

     CARBON CONVERSION                        90.8  PCT

     COMBUSTION EFFICIENCY                    92.2  PCT

     SULFUR CAPTURE                           74.0  PCT
     (NORMALIZED)                             80.5  PCT

     CALCIUM UTILIZATION
        IN SPENT BED                          36.2  PCT
        IN CYCLONE ASH                        19.5  PCT
        IN BAGHOUSE ASH                       38.9  PCT


     O2 CONCENTRATION =    3.0  PCT
     SO2 CONCENTRATION(3% O2) =  1132.  PPM            2.53  LB/MBTU
     NOX CONCENTRATION(3% O2) =   157.  PPM            0.22  LB/MBTU
     CO CONCENTRATION(3% O2) =    888.  PPM            0.75  LB/MBTU

     AVERAGE BED TEMPERATURE =        1649.  DEGREES F
     FREEBOARD #1 TEMPERATURE =       1666.  DEGREES F
     FREEBOARD #2 TEMPERATURE =       1656.  DEGREES F
     FREEBOARD #3 TEMPERATURE =       1523.  DEGREES F
     FREEBOARD #4 TEMPERATURE =       1013.  DEGREES F
     PREHEAT TEMPERATURE =             405.  DEGREES F

     FUEL FEED RATE =          81.0  LBS/HR
     LIMESTONE FEED RATE =     28.0  LBS/HR
     FINES RECYCLE RATE =       0.0  LBS/HR
     FINES RECYCLE RATIO =      0.0

     PLATE DP =                 7.1  IN H2O
     BED DP =                  20.5  IN H2O
     BED HEIGHT =              28.5  INCHES
```

TEST NUMBER =63.06 TEST DATE = 9/14/83 TEST TIME = 0830-1130

MATERIAL BALANCE (LBS/HR)

	TOTAL	CARBON	SULFUR	CALCIUM
FUEL	79.2	31.5	2.61	0.32
LIMESTONE	27.0	3.0	0.00	9.71
FLUIDIZING AIR	361.6			
TRANSPORT AIR	96.9			
PURGE AIR	16.1			
PROBE AIR	32.3			
RECYCLE AIR	0.0			
TOTAL IN	613.1	34.5	2.61	10.03
BED LETDOWN	12.2	0.0	1.38	4.91
CYCLONE HOPPER OVERFLOW	16.5	1.0	1.03	6.03
CYCLONE OUTLET DUST	0.8	0.1	0.04	0.12
FLUE GAS	585.6	33.4*	1.14	
TOTAL OUT	615.2	34.5	3.58	11.06
% ACCOUNTED FOR	100.3	100.0	137.1	110.3

* CO2 IN FLUE GAS CALCULATED BY DIFFERENCE

CHEMICAL ANALYSIS (WT. PERCENT)

FUEL TYPE	H2O*	C*	H	N	S*	O	ASH	BTU/LB
UNBEN. CWS	40.20	39.82	2.51	0.62	3.30	3.82	8.73	6970

LIMESTONE TYPE	H2O	C(DRY%)	CAO(DRY%)	MGO(DRY%)	SO3(DRY%)	CO2(DRY%)
REED	0.10		50.40	0.48	0.00	40.70
BED LETDOWN	0.00	0.04	56.30		28.28	0.04
CYCLONE HOPPER OVERFLOW	0.00	5.20	51.20		15.61	3.90
CYCLONE OUTLET DUST	8.20	8.30	21.70		12.39	3.15

* C, S, AND H2O MEASURED FOR EACH TEST
H, N, O, ASH, AND BTU/LB BASED ON COMPOSITE OF ALL TESTS

```
TEST NUMBER =63.06      TEST DATE = 9/14/83      TEST TIME = 0830-1130

SUMMARY OF RESULTS

     SUPERFICIAL VELOCITY
        BASED ON AIR                               5.8  FT/SEC
        BASED ON FLUE GAS                          6.8  FT/SEC

     EXCESS AIR                                   16.6  PCT

     CALCIUM/SULFUR RATIO                          3.0

     CARBON CONVERSION                            97.1  PCT

     COMBUSTION EFFICIENCY                        97.6  PCT

     SULFUR CAPTURE                               56.5  PCT
     (NORMALIZED)                                 68.3  PCT

     CALCIUM UTILIZATION
        IN SPENT BED                              35.2  PCT
        IN CYCLONE ASH                            21.3  PCT
        IN BAGHOUSE ASH                           40.0  PCT


     O2 CONCENTRATION =     3.1  PCT
     SO2 CONCENTRATION(3% O2) =  1830   PPM          4.11  LB/MBTU
     NOX CONCENTRATION(3% O2) =   202.  PPM          0.28  LB/MBTU
     CO CONCENTRATION(3% O2) =    767.  PPM          0.65  LB/MBTU

     AVERAGE BED TEMPERATURE =        1731.  DEGREES F
     FREEBOARD #1 TEMPERATURE =       1742.  DEGREES F
     FREEBOARD #2 TEMPERATURE =       1719.  DEGREES F
     FREEBOARD #3 TEMPERATURE =       1569.  DEGREES F
     FREEBOARD #4 TEMPERATURE =       1050.  DEGREES F
     PREHEAT TEMPERATURE =             415.  DEGREES F

     FUEL FEED RATE =          79.2  LBS/HR
     LIMESTONE FEED RATE =     27.0  LBS/HR
     FINES RECYCLE RATE =       0.0  LBS/HR
     FINES RECYCLE RATIO =      0.0

     PLATE DP =                 5.4  IN H2O
     BED DP =                  20.8  IN H2O
     BED HEIGHT =              30.0  INCHES
```

TEST NUMBER =63.07   TEST DATE = 9/14/83   TEST TIME = 1200-1500

MATERIAL BALANCE (LBS/HR)

	TOTAL	CARBON	SULFUR	CALCIUM
FUEL	85.1	34.0	2.95	0.34
LIMESTONE	10.0	1.1	0.00	3.60
FLUIDIZING AIR	405.5			
TRANSPORT AIR	96.4			
PURGE AIR	16.4			
PROBE AIR	32.2			
RECYCLE AIR	0.0			
TOTAL IN	645.6	35.2	2.95	3.94
BED LETDOWN	3.4	0.0	0.43	1.30
CYCLONE HOPPER OVERFLOW	13.3	2.3	0.66	2.87
CYCLONE OUTLET DUST	0.9	0.1	0.04	0.12
FLUE GAS	627.1	32.8*	1.20	
TOTAL OUT	644.7	35.2	2.33	4.30
% ACCOUNTED FOR	99.9	100.0	79.0	109.1

* CO2 IN FLUE GAS CALCULATED BY DIFFERENCE

CHEMICAL ANALYSIS (WT. PERCENT)

FUEL TYPE	H2O*	C*	H	N	S*	O	ASH	BTU/LB
UNBEN. CWS	39.50	40.00	2.51	0.62	3.47	3.82	8.73	6970.

LIMESTONE TYPE	H2O	C(DRY%)	CAO(DRY%)	MGO(DRY%)	SO3(DRY%)	CO2(DRY%)
REED	0.10		50.40	0.48	0.00	40.70
BED LETDOWN	0.00	0.01	53.60		31.57	0.11
CYCLONE HOPPER OVERFLOW	0.30	16.50	30.30		12.44	3.26
CYCLONE OUTLET DUST	2.60	8.30	19.90		11.22	1.70

* C, S, AND H2O MEASURED FOR EACH TEST
  H, N, O, ASH, AND BTU/LB BASED ON COMPOSITE OF ALL TESTS

```
TEST NUMBER =63.07      TEST DATE = 9/14/83      TEST TIME = 1200-1500


SUMMARY OF RESULTS

     SUPERFICIAL VELOCITY
        BASED ON AIR                               5.8  FT/SEC
        BASED ON FLUE GAS                          6.6  FT/SEC

     EXCESS AIR                                   23.3  PCT

     CALCIUM/SULFUR RATIO                          1.0

     CARBON CONVERSION                            93.4  PCT

     COMBUSTION EFFICIENCY                        94.5  PCT

     SULFUR CAPTURE                               59.3  PCT
     (NORMALIZED)                                 48.4  PCT

     CALCIUM UTILIZATION
        IN SPENT BED                              41.2  PCT
        IN CYCLONE ASH                            28.7  PCT
        IN BAGHOUSE ASH                           39.5  PCT


     O2 CONCENTRATION =      4.1   PCT
     SO2 CONCENTRATION(3% O2) =   1811.   PPM          4.06  LB/MBTU
     NOX CONCENTRATION(3% O2) =    175.   PPM          0.24  LB/MBTU
     CO CONCENTRATION(3% O2) =     479.   PPM          0.40  LB/MBTU

     AVERAGE BED TEMPERATURE =        1548.  DEGREES F
     FREEBOARD #1 TEMPERATURE =       1628.  DEGREES F
     FREEBOARD #2 TEMPERATURE =       1679.  DEGREES F
     FREEBOARD #3 TEMPERATURE =       1581.  DEGREES F
     FREEBOARD #4 TEMPERATURE =       1041.  DEGREES F
     PREHEAT TEMPERATURE =             403.  DEGREES F

     FUEL FEED RATE =          85.1  LBS/HR
     LIMESTONE FEED RATE =     10.0  LBS/HR
     FINES RECYCLE RATE =       0.0  LBS/HR
     FINES RECYCLE RATIO =      0.0

     PLATE DP =                 6.2  IN H2O
     BED DP =                  19.9  IN H2O
     BED HEIGHT =              24.8  INCHES
```

TEST NUMBER =63.08 TEST DATE = 9/15/83 TEST TIME = 0830-1130

MATERIAL BALANCE (LBS/HR)

	TOTAL	CARBON	SULFUR	CALCIUM
FUEL	86.1	34.1	3.18	0.35
LIMESTONE	30.0	3.3	0.00	10.79
FLUIDIZING AIR	380.4			
TRANSPORT AIR	103.8			
PURGE AIR	15.7			
PROBE AIR	32.3			
RECYCLE AIR	38.0			
TOTAL IN	686.3	37.4	3.18	11.14
BED LETDOWN	23.3	0.0	2.82	8.85
CYCLONE HOPPER OVERFLOW	13.3	2.0	0.63	3.19
CYCLONE OUTLET DUST	2.3	0.2	0.11	0.30
FLUE GAS	657.3	35.2*	0.56	
TOTAL OUT	696.2	37.4	4.12	12.34
% ACCOUNTED FOR	101.4	100.0	129.8	110.8

* CO2 IN FLUE GAS CALCULATED BY DIFFERENCE

CHEMICAL ANALYSIS (WT. PERCENT)

FUEL TYPE	H2O*	C*	H	N	S*	O	ASH	BTU/LB
UNBEN. CWS	39.50	39.58	2.51	0.62	3.69	3.82	8.73	6970.

LIMESTONE TYPE	H2O	C(DRY%)	CAO(DRY%)	MGO(DRY%)	SO3(DRY%)	CO2(DRY%)
REED	0.10		50.40	0.48	0.00	40.70
BED LETDOWN	0.00	0.00	53.20		30.25	0.17
CYCLONE HOPPER OVERFLOW	0.40	13.80	33.70		11.82	3.80
CYCLONE OUTLET DUST	2.00	8.20	18.60		12.63	1.33

* C, S, AND H2O MEASURED FOR EACH TEST
H, N, O, ASH, AND BTU/LB BASED ON COMPOSITE OF ALL TESTS

```
TEST NUMBER =63.08      TEST DATE = 9/15/83       TEST TIME = 0830-1130


SUMMARY OF RESULTS

     SUPERFICIAL VELOCITY
        BASED ON AIR                            6.0  FT/SEC
        BASED ON FLUE GAS                       6.9  FT/SEC

     EXCESS AIR                                17.3  PCT

     CALCIUM/SULFUR RATIO                       2.7

     CARBON CONVERSION                         94.1  PCT

     COMBUSTION EFFICIENCY                     95.1  PCT

     SULFUR CAPTURE                            82.3  PCT
     (NORMALIZED)                              86.3  PCT

     CALCIUM UTILIZATION
        IN SPENT BED                           39.8  PCT
        IN CYCLONE ASH                         24.6  PCT
        IN BAGHOUSE ASH                        47.5  PCT


     O2 CONCENTRATION =     3.2  PCT
     SO2 CONCENTRATION(3% O2) =    809.   PPM          1.88  LB/MBTU
     NOX CONCENTRATION(3% O2) =    130.   PPM          0.19  LB/MBTU
     CO CONCENTRATION(3% O2) =    1187.   PPM          1.04  LB/MBTU


     AVERAGE BED TEMPERATURE =        1562.  DEGREES F
     FREEBOARD #1 TEMPERATURE =          0.  DEGREES F
     FREEBOARD #2 TEMPERATURE =       1596.  DEGREES F
     FREEBOARD #3 TEMPERATURE =       1518.  DEGREES F
     FREEBOARD #4 TEMPERATURE =       1077.  DEGREES F
     PREHEAT TEMPERATURE =             416.  DEGREES F


     FUEL FEED RATE =         86.1  LBS/HR
     LIMESTONE FEED RATE =    30.0  LBS/HR
     FINES RECYCLE RATE =     60.0  LBS/HR
     FINES RECYCLE RATIO =     0.7


     PLATE DP =                4.6  IN H2O
     BED DP =                 22.0  IN H2O
     BED HEIGHT =             28.0  INCHES
```

TEST NUMBER =63.09   TEST DATE = 9/15/83   TEST TIME = 1200-1500

MATERIAL BALANCE (LBS/HR)

	TOTAL	CARBON	SULFUR	CALCIUM
FUEL	62.2	24.8	2.11	0.25
LIMESTONE	22.0	2.4	0.00	7.91
FLUIDIZING AIR	278.9			
TRANSPORT AIR	99.8			
PURGE AIR	16.1			
PROBE AIR	32.1			
RECYCLE AIR	0.0			
TOTAL IN	511.1	27.2	2.11	8.16
BED LETDOWN	9.4	0.0	1.13	3.69
CYCLONE HOPPER OVERFLOW	12.5	2.0	0.57	3.69
CYCLONE OUTLET DUST	1.1	0.1	0.05	0.14
FLUE GAS	486.5	25.1*	0.45	
TOTAL OUT	509.5	27.2	2.20	7.52
% ACCOUNTED FOR	99.7	100.0	104.3	92.2

* CO2 IN FLUE GAS CALCULATED BY DIFFERENCE

CHEMICAL ANALYSIS (WT. PERCENT)

FUEL TYPE	H2O*	C*	H	N	S*	O	ASH	BTU/LB
UNBEN. CWS	39.30	39.81	2.51	0.62	3.40	3.82	8.73	6970

LIMESTONE TYPE	H2O	C(DRY%)	CAO(DRY%)	MGO(DRY%)	SO3(DRY%)	CO2(DRY%)
REED	0.10		50.40	0.48	0.00	40.70
BED LETDOWN	0.00	0.00	54.90		30.14	0.16
CYCLONE HOPPER OVERFLOW	0.30	14.70	41.50		11.50	5.60
CYCLONE OUTLET DUST	0.80	8.10	18.50		10.96	0.91

* C, S, AND H2O MEASURED FOR EACH TEST
H, N, O, ASH, AND BTU/LB BASED ON COMPOSITE OF ALL TESTS

```
TEST NUMBER =63.09       TEST DATE = 9/15/83       TEST TIME = 1200-1500

SUMMARY OF RESULTS

     SUPERFICIAL VELOCITY
        BASED ON AIR                                4.5  FT/SEC
        BASED ON FLUE GAS                           5.2  FT/SEC

     EXCESS AIR                                    17.3  PCT

     CALCIUM/SULFUR RATIO                           3.0

     CARBON CONVERSION                             92.2  PCT

     COMBUSTION EFFICIENCY                         93.6  PCT

     SULFUR CAPTURE                                78.7  PCT
     (NORMALIZED)                                  79.6  PCT

     CALCIUM UTILIZATION
        IN SPENT BED                               38.4  PCT
        IN CYCLONE ASH                             19.4  PCT
        IN BAGHOUSE ASH                            41.5  PCT


     O2 CONCENTRATION =      3.2  PCT
     SO2 CONCENTRATION(3% O2) =     874.   PPM              2.08  LB/MBTU
     NOX CONCENTRATION(3% O2) =     101.   PPM              0.15  LB/MBTU
     CO CONCENTRATION(3% O2) =      304.   PPM              0.27  LB/MBTU


     AVERAGE BED TEMPERATURE =           1552.   DEGREES F
     FREEBOARD #1 TEMPERATURE =             0.   DEGREES F
     FREEBOARD #2 TEMPERATURE =          1652.   DEGREES F
     FREEBOARD #3 TEMPERATURE =          1584.   DEGREES F
     FREEBOARD #4 TEMPERATURE =           962.   DEGREES F
     PREHEAT TEMPERATURE =                444.   DEGREES F


     FUEL FEED RATE =          62.2  LBS/HR
     LIMESTONE FEED RATE =     22.0  LBS/HR
     FINES RECYCLE RATE =       0.0  LBS/HR
     FINES RECYCLE RATIO =      0.0


     PLATE DP =                 4.3  IN H2O
     BED DP =                  23.1  IN H2O
     BED HEIGHT =              27.3  INCHES
```

TEST SERIES 64 -- THICKENER UNDERFLOW

TEST NUMBER =64.01 TEST DATE = 10/21/83 TEST TIME = 1100-1500

MATERIAL BALANCE (LBS/HR)

	TOTAL	CARBON	SULFUR	CALCIUM
THICKENER UNDERFLOW	201.0	23.1	0.14	0.83
COAL	13.0	9.3	0.31	0.01
LIMESTONE	0.0	0.0	0.00	0.00
FLUIDIZING AIR	379.5			
TRANSPORT AIR	102.5			
PURGE AIR	21.1			
PROBE AIR	31.9			
RECYCLE AIR	0.0			
TOTAL IN	749.1	32.4	0.45	0.84
BED LETDOWN	0.0	0.0	0.00	0.00
CYCLONE HOPPER OVERFLOW	22.5	1.8	0.12	0.59
CYCLONE OUTLET DUST	3.0	0.2	0.12	0.34
FLUE GAS	715.3	30.4*	0.33	
TOTAL OUT	740.8	32.4	0.58	0.93
% ACCOUNTED FOR	98.9	100.0	127.1	111.3

* CO2 IN FLUE GAS CALCULATED BY DIFFERENCE

CHEMICAL ANALYSIS (WT. PERCENT)

FUEL TYPE	H2O	C	H	N	S	O	ASH	BTU/LB
THICKENER UN	69.40	11.50	0.69	0.15	0.07	3.09	15.10	1650.
COAL	3.00	71.20	4.90	1.36	2.40	7.89	9.60	12820.

LIMESTONE TYPE	H2O	C(DRY%)	CAO(DRY%)	MGO(DRY%)	SO3(DRY%)	CO2(DRY%)
SAND	0.00		0.05	0.00	0.00	0.02
BED LETDOWN	0.00	0.07	0.45		0.30	0.04
CYCLONE HOPPER OVERFLOW	0.20	7.80	3.70		1.37	0.43
CYCLONE OUTLET DUST	3.30	7.10	16.40		10.70	3.10

```
TEST NUMBER =64.01        TEST DATE = 10/21/83        TEST TIME = 1100-1500


SUMMARY OF RESULTS

     SUPERFICIAL VELOCITY
        BASED ON AIR                                5.4  FT/SEC
        BASED ON FLUE GAS                           7.5  FT/SEC

     EXCESS AIR                                    14.8  PCT

     CALCIUM/SULFUR RATIO                           0.0

     CARBON CONVERSION                             94.0  PCT

     COMBUSTION EFFICIENCY                         94.3  PCT

     SULFUR CAPTURE                                27.5  PCT
     (NORMALIZED)                                  51.9  PCT

     CALCIUM UTILIZATION
        IN SPENT BED                               46.7  PCT
        IN CYCLONE ASH                             25.9  PCT
        IN BAGHOUSE ASH                            45.7  PCT


     O2 CONCENTRATION =      2.8  PCT
     SO2 CONCENTRATION(3% O2) =     433.   PPM             1.32  LB/MBTU
     NOX CONCENTRATION(3% O2) =     112.   PPM             0.15  LB/MBTU
     CO CONCENTRATION(3% O2) =      479.   PPM             0.40  LB/MBTU


     AVERAGE BED TEMPERATURE =        1493.   DEGREES F
     FREEBOARD #1 TEMPERATURE =       1529.   DEGREES F
     FREEBOARD #2 TEMPERATURE =       1582.   DEGREES F
     FREEBOARD #3 TEMPERATURE =       1551.   DEGREES F
     FREEBOARD #4 TEMPERATURE =       1081.   DEGREES F
     PREHEAT TEMPERATURE =             831.   DEGREES F


     FUEL FEED RATE =          201.0  LBS/HR
     LIMESTONE FEED RATE =       0.0  LBS/HR
     FINES RECYCLE RATE =        0.0  LBS/HR
     FINES RECYCLE RATIO =       0.0


     PLATE DP =                  5.0  IN H2O
     BED DP =                   26.8  IN H2O
     BED HEIGHT =               33.0  INCHES
```

Appendix C

HEAT TRANSFER ANALYSIS FOR TEST SERIES 62 AND 63

SUMMARY OF HEAT TRANSFER INFORMATION

DATE	TEST	TUBE NUMBER	DFDD (IN)	FLOW RATE (LB/HR)	FLUID TEMP (F)		HEAT TRANSFER COEF (BTU/HR-F-FT2)					HEAT REMOVED (BTU/HR)
					IN	OUT	OVALL	OUTFILM	INFILM	RAD	OUT-RAD	
1983.216	62.01	1	13.00	850.8	73.	94.	39.12	44.52	645.99	20.50	24.02	17867
1983.216	62.01	2	18.00	850.8	73.	101.	52.30	62.40	648.09	20.58	41.82	23822
1983.216	62.01	3	23.00	850.8	73.	96.	42.88	49.45	646.61	20.52	28.92	19568
						AVG=	44.77					AVG= 20419.
1983.216	62.01	4	147.00	405.4	74.	83.	10.13	10.60	399.48	0.00	0.00	3648.
1983.216	62.01	5	149.50	405.4	74.	81.	7.88	8.15	398.97	0.00	0.00	2838.
1983.216	62.01	6	152.00	405.4	74.	76.	2.24	2.27	397.62	0.00	0.00	811.
1983.216	62.01	7	154.50	405.4	74.	76.	2.24	2.27	397.62	0.00	0.00	811.
1983.216	62.01	8	157.00	405.4	74.	78.	4.49	4.58	398.17	0.00	0.00	1622.
							AVE=	5.57				AVE= 1946.
1983.216	62.02	1	13.00	1080.9	73.	88.	35.36	39.13	796.82	20.51	18.62	16213.
1983.216	62.02	2	18.00	1080.9	73.	92.	44.85	51.09	798.47	20.55	30.53	20537.
1983.216	62.02	3	23.00	1080.9	73.	91.	42.49	48.05	798.07	20.54	27.51	19456.
						AVG=	40.90					AVG= 18735.
1983.216	62.02	4	147.00	390.4	74.	86.	12.51	13.26	376.32	0.00	0.00	4684.
1983.216	62.02	5	149.50	390.4	74.	84.	10.41	10.93	375.87	0.00	0.00	3904.
1983.216	62.02	6	152.00	390.4	74.	79.	5.19	5.32	374.68	0.00	0.00	1952.
1983.216	62.02	7	154.50	390.4	74.	78.	4.16	4.24	374.43	0.00	0.00	1561.
1983.216	62.02	8	157.00	390.4	74.	79.	5.19	5.32	374.68	0.00	0.00	1952.
							AVE=	7.81				AVE= 2811.
1983.220	62.03	1	13.00	750.7	73.	99.	42.97	50.13	580.75	20.42	29.70	19518.
1983.220	62.03	2	18.00	750.7	73.	105.	52.99	64.29	582.27	20.49	43.81	24022.
1983.220	62.03	3	23.00	750.7	73.	99.	42.97	50.13	580.75	20.42	29.70	19518.
						AVG=	46.31					AVG= 21020.
1983.220	62.03	4	147.00	466.7	73.	80.	9.32	9.67	459.57	0.00	0.00	3267.
1983.220	62.03	5	149.50	466.7	73.	77.	5.32	5.43	458.61	0.00	0.00	1867.
1983.220	62.03	6	152.00	466.7	73.	76.	3.99	4.05	458.28	0.00	0.00	1400.
1983.220	62.03	7	154.50	466.7	73.	75.	2.66	2.68	457.94	0.00	0.00	933.
1983.220	62.03	8	157.00	466.7	73.	75.	2.66	2.68	457.94	0.00	0.00	933.
							AVE=	4.91				AVE= 1680.
1983.220	62.04	1	13.00	932.1	73.	97.	46.20	53.72	670.00	23.07	30.65	22371.
1983.220	62.04	2	18.00	932.1	73.	103.	57.86	70.14	671.77	23.15	46.99	27964.
1983.220	62.04	3	23.00	932.1	73.	98.	48.13	56.34	670.30	23.08	33.26	23303.
						AVG=	50.73					AVG= 24546.
1983.220	62.04	4	147.00	475.4	74.	81.	9.12	9.46	454.35	0.00	0.00	3328.
1983.220	62.04	5	149.50	475.4	74.	78.	5.20	5.31	453.44	0.00	0.00	1902.
1983.220	62.04	6	152.00	475.4	74.	77.	3.90	3.96	453.13	0.00	0.00	1426.
1983.220	62.04	7	154.50	475.4	74.	76.	2.60	2.63	452.81	0.00	0.00	951.
1983.220	62.04	8	157.00	475.4	74.	76.	2.60	2.63	452.81	0.00	0.00	951.
							AVE=	4.80				AVE= 1712.
1983.221	62.05	1	13.00	936.6	73.	100	49.27	58.18	643.21	25.98	32.21	25288.
1983.221	62.05	2	18.00	936.6	73.	107.	62.19	77.07	645.07	26.07	51.00	31844.
1983.221	62.05	3	23.00	936.6	73	101.	51.13	60.79	643.49	25.99	34.79	26225.
						AVG=	54.20					AVG= 27786.
1983.221	62.05	4	147.00	499.2	74.	79.	7.71	7.93	514.96	0.00	0.00	2496.
1983.221	62.05	5	149.50	499.2	74.	77.	4.62	4.70	514.21	0.00	0.00	1498.
1983.221	62.05	6	152.00	499.2	74.	78.	6.16	6.30	514.59	0.00	0.00	1997.
1983.221	62.05	7	154.50	499.2	74.	75.	1.54	1.55	513.44	0.00	0.00	499.
1983.221	62.05	8	157.00	499.2	74.	75	1.54	1.55	513.44	0.00	0.00	499
							AVE=	4.40				AVE= 1398.

```
DATE      TEST   TUBE     DFDD    FLOW   FLUID TEMP (F)                    HEAT TRANSFER COEF.
                NUMBER            RATE     IN      OUT                        (BTU/HR-F-FT2)                     HEAT REMOVED
                          (IN)  (LB/HR)                    OVALL    OUTFILM    INFILM     RAD     OUT-RAD     (BTU/HR)
------------------------------------------------------------------------------------------------------------------------
1983.221 62.06   1      13.00   941.8     73      92       39.23     44.33     707.83    20.39     23.93        17894.
1983.221 62.06   2      18.00   941.8     73      98       51.73     60.94     709.88    20.46     40.48        23545.
1983.221 62.06   3      23.00   941.8     73.     94.      43.39     49.71     708.53    20.42     29.29        19778.
                                                     AVG=  44.79                                        AVG=  20405.
1983.221 62.06   4     147.00   476.7     74      81        9.16      9.50     456.11     0.00      0.00         3337.
1983.221 62.06   5     149.50   476.7     74      78.       5.23      5.34     455.20     0.00      0.00         1907.
1983.221 62.06   6     152.00   476.7     74.     78.       5.23      5.34     455.20     0.00      0.00         1907.
1983.221 62.06   7     154.50   476.7     74      76.       2.61      2.64     454.57     0.00      0.00          953.
1983.221 62.06   8     157.00   476.7     74.     76.       2.61      2.64     454.57     0.00      0.00          953.
                                                             AVE=   5.09                                AVE=   1811.
------------------------------------------------------------------------------------------------------------------------
1983.222 62.07   1      13.00   879.4     73      100      52.27     62.12     668.96    20.43     41.69        23744.
1983.222 62.07   2      18.00   879.4     73.     107      66.00     82.49     670.97    20.51     61.97        29899.
1983.222 62.07   3      23.00   879.4     73.     100.     52.27     62.12     668.96    20.43     41.69        23744.
                                                     AVG=  56.85                                        AVG=  25796.
1983.222 62.07   4     147.00   440.4     74      80.       7.83      8.08     448.86     0.00      0.00         2642.
1983.222 62.07   5     149.50   440.4     74      76.       2.61      2.63     447.59     0.00      0.00          881.
1983.222 62.07   6     152.00   440.4     74.     78.       5.22      5.33     448.23     0.00      0.00         1762.
1983.222 62.07   7     154.50   440.4     74.     75.       1.30      1.31     447.26     0.00      0.00          440.
1983.222 62.07   8     157.00   440.4     74.     75.       1.30      1.31     447.26     0.00      0.00          440.
                                                             AVE=   3.73                                AVE=   1233.
------------------------------------------------------------------------------------------------------------------------
1983.222 62.08   1      13.00  1042.6     73.     93.      46.73     53.61     788.70    19.59     34.02        20853.
1983.222 62.08   2      18.00  1042.6     73      99.      60.88     73.07     790.97    19.66     53.41        27109.
1983.222 62.08   3      23.00  1042.6     73.     95.      51.44     59.89     789.48    19.61     40.28        22938.
                                                     AVG=  53.02                                        AVG=  23633.
1983.222 62.08   4     147.00   430.4     74      79.       6.37      6.53     439.18     0.00      0.00         2152.
1983.222 62.08   5     149.50   430.4     74.     77        3.82      3.88     438.56     0.00      0.00         1291.
1983.222 62.08   6     152.00   430.4     74.     77        3.82      3.88     438.56     0.00      0.00         1291.
1983.222 62.08   7     154.50   430.4     74      75.       1.27      1.28     437.91     0.00      0.00          430.
1983.222 62.08   8     157.00   430.4     74.     75.       1.27      1.28     437.91     0.00      0.00          430.
                                                             AVE=   3.37                                AVE=   1119.
------------------------------------------------------------------------------------------------------------------------
1983.223 62.09   1      13.00   900.8     73.     95.      43.39     49.90     679.81    20.54     29.36        19819.
1983.223 62.09   2      18.00   900.8     73.     101.     55.34     66.35     681.69    20.60     45.74        25224.
1983.223 62.09   3      23.00   900.8     73      96.      45.37     52.52     680.13    20.55     31.97        20719.
                                                     AVG=  48.03                                        AVG=  21920.
1983.223 62.09   4     147.00   431.7     74.     82.       9.90     10.32     431.19     0.00      0.00         3453.
1983.223 62.09   5     149.50   431.7     74.     78.       4.94      5.04     430.03     0.00      0.00         1727.
1983.223 62.09   6     152.00   431.7     74      78.       4.94      5.04     430.03     0.00      0.00         1727.
1983.223 62.09   7     154.50   431.7     74.     76.       2.47      2.49     429.42     0.00      0.00          863.
1983.223 62.09   8     157.00   431.7     74.     76.       2.47      2.49     429.42     0.00      0.00          863.
                                                             AVE=   5.08                                AVE=   1727.
------------------------------------------------------------------------------------------------------------------------
1983.223 62.10   1      13.00   850.8     73      95.      41.04     47.02     646.64    20.48     26.54        18717.
1983.223 62.10   2      18.00   850.8     73.     102.     54.21     65.12     648.72    20.56     44.56        24673.
1983.223 62.10   3      23.00   850.8     73.     96.      42.91     49.48     646.95    20.49     28.99        19568.
                                                     AVG=  46.05                                        AVG=  20986.
1983.223 62.10   4     147.00   426.6     74.     83.      10.66     11.15     417.51     0.00      0.00         3840.
1983.223 62.10   5     149.50   426.6     74      79.       5.91      6.06     416.42     0.00      0.00         2133.
1983.223 62.10   6     152.00   426.6     74      78.       4.73      4.82     416.14     0.00      0.00         1707.
1983.223 62.10   7     154.50   426.6     74      76.       2.36      2.39     415.56     0.00      0.00          853.
1983.223 62.10   8     157.00   426.6     74.     76.       2.36      2.39     415.56     0.00      0.00          853.
                                                             AVE=   5.36                                AVE=   1877.
```

					FLUID TEMP (F)		HEAT TRANSFER COEF (BTU/HR-F-FT2)					
DATE	TEST	TUBE NUMBER	DFDD (IN)	FLOW RATE (LB/HR)	IN	OUT	OVALL	OUTFILM	INFILM	RAD	OUT-RAD	HEAT REMOVED (BTU/HR)
1983.252	63.01	1	13.00	1201.1	74	92	47.76	54.43	886.03	20.14	34.29	21620
1983.252	63.01	2	18.00	1201.1	74	96	58.45	68.76	887.76	20.19	48.57	26425.
1983.252	63.01	3	23.00	1201.1	74	94	53.10	61.48	886.91	20.16	41.31	24022.
						AVG=	53.11				AVG=	24022.
1983.252	63.01	4	147.00	445.4	75	83	10.13	10.56	441.03	0.00	0.00	3563.
1983.252	63.01	5	149.50	445.4	75	79	5.06	5.16	439.88	0.00	0.00	1782.
1983.252	63.01	6	152.00	445.4	75	78	3.79	3.85	439.58	0.00	0.00	1336.
1983.252	63.01	7	154.50	445.4	75	77	2.53	2.55	439.27	0.00	0.00	891.
1983.252	63.01	8	157.00	445.4	75	77	2.53	2.55	439.27	0.00	0.00	891.
							AVE=	4.94			AVE=	1693.
1983.255	63.02	1	13.00	957.0	74	96	46.32	53.50	720.66	20.40	33.10	21055.
1983.255	63.02	2	18.00	957.0	74	101	56.93	68.15	722.29	20.46	47.69	25840
1983.255	63.02	3	23.00	957.0	74	97	48.43	56.32	720.99	20.41	35.91	22012.
						AVG=	50.56				AVG=	22969.
1983.255	63.02	4	147.00	412.9	74	82	9.83	10.25	425.71	0.00	0.00	3303.
1983.255	63.02	5	149.50	412.9	74	80	7.37	7.60	425.14	0.00	0.00	2477.
1983.255	63.02	6	152.00	412.9	74	77	3.68	3.73	424.24	0.00	0.00	1239.
1983.255	63.02	7	154.50	412.9	74	78	4.91	5.01	424.54	0.00	0.00	1652.
1983.255	63.02	8	157.00	412.9	74	78	4.91	5.01	424.54	0.00	0.00	1652.
							AVE=	6.32			AVE=	2064
1983.255	63.03	1	13.00	1027.8	73	91	40.79	46.02	768.41	20.17	25.85	18501.
1983.255	63.03	2	18.00	1027.8	73	95	49.92	57.97	769.94	20.22	37.76	22613.
1983.255	63.03	3	23.00	1027.8	73	93	45.35	51.90	769.19	20.19	31.71	20557.
						AVG=	45.35				AVG=	20557.
1983.255	63.03	4	147.00	401.6	74	87	13.87	14.78	384.48	0.00	0.00	5221.
1983.255	63.03	5	149.50	401.6	74	85	11.73	12.37	384.03	0.00	0.00	4418.
1983.255	63.03	6	152.00	401.6	74	78	4.25	4.33	382.34	0.00	0.00	1607.
1983.255	63.03	7	154.50	401.6	74	81	7.45	7.71	383.09	0.00	0.00	2811.
1983.255	63.03	8	157.00	401.6	74	80	6.38	6.57	382.84	0.00	0.00	2410.
							AVE=	9.15			AVE=	3293.
1983.256	63.04	1	13.00	945.3	73	96	47.64	55.34	710.49	20.52	34.82	21743.
1983.256	63.04	2	18.00	945.3	73	102	60.19	73.01	712.43	20.59	52.42	27415.
1983.256	63.04	3	23.00	945.3	73	98	51.82	61.06	711.15	20.54	40.51	23633.
						AVG=	53.22				AVG=	24263.
1983.256	63.04	4	147.00	488.0	74	80	8.25	8.52	474.26	0.00	0.00	2928.
1983.256	63.04	5	149.50	488.0	74	77	4.12	4.19	473.28	0.00	0.00	1464.
1983.256	63.04	6	152.00	488.0	74	77	4.12	4.19	473.28	0.00	0.00	1464.
1983.256	63.04	7	154.50	488.0	74	76	2.75	2.78	472.95	0.00	0.00	976.
1983.256	63.04	8	157.00	488.0	74	76	2.75	2.78	472.95	0.00	0.00	976.
							AVE=	4.49			AVE=	1561.
1983.257	63.05	1	13.00	1018.5	73	93	42.12	47.95	725.41	22.90	25.04	20370.
1983.257	63.05	2	18.00	1018.5	73	87	29.43	32.17	723.20	22.83	9.34	14259.
1983.257	63.05	3	23.00	1018.5	73	96	48.47	56.34	726.45	22.94	33.40	23425
						AVG=	40.01				AVG=	19351
1983.257	63.05	4	147.00	481.7	73	80	9.29	9.64	461.34	0.00	0.00	3372
1983.257	63.05	5	149.50	481.7	73	77	5.31	5.42	460.39	0.00	0.00	1927
1983.257	63.05	6	152.00	481.7	73	76	3.98	4.04	460.06	0.00	0.00	1445
983.257	63.05	7	154.50	481.7	73	76	3.98	4.04	460.06	0.00	0.00	1445
983.257	63.05	8	157.00	481.7	73	75	2.65	2.68	459.73	0.00	0.00	963
							AVE=	5.16			AVE=	1830

```
DATE       TEST    TUBE     DFDD    FLOW    FLUID TEMP (F)                  HEAT TRANSFER COEF
                   NUMBER           RATE     IN       OUT                     (BTU/HR-F-FT2)                                HEAT REMOVED
                                    (IN)   (LB/HR)                      OVALL    OUTFILM    INFILM     RAD      OUT-RAD     (BTU/HR)

------------------------------------------------------------------------------------------------------------------------------------
1983 257 63.06   1     13.00   1103.3    73       93       43.36     49.42     748.56    25.35     24.07        22066
1983 257 63.06   2     18.00   1103.3    73       99       56.47     67.19     750.62    25.43     41.76        28686
1983 257 63.06   3     23.00   1103.3    73       95       47.72     55.17     749.26    25.38     29.79        24273
                                                      AVG= 49.18                                          AVG= 25008
1983 257 63.06   4    147.00    464.2    74       83       11.15     11.67     436.86     0.00      0.00         4178
1983 257 63.06   5    149.50    464.2    74       78        4.94      5.04     435.46     0.00      0.00         1857
1983 257 63.06   6    152.00    464.2    74       77        3.71      3.76     435.16     0.00      0.00         1393
1983 257 63.06   7    154.50    464.2    74       76        2.47      2.49     434.86     0.00      0.00          928
1983 257 63.06   8    157.00    464.2    74       76        2.47      2.49     434.86     0.00      0.00          928
                                                                AVE=  5.09                                AVE=  1857
------------------------------------------------------------------------------------------------------------------------------------
1983 257 63.07   1     13.00   1015.0    73       92       42.60     48.38     761.40    20.10     28.28        19286
1983 257 63.07   2     18.00   1015.0    73       97       53.92     63.50     763.25    20.16     43.35        24361
1983 257 63.07   3     23.00   1015.0    73       94       47.12     54.28     762.16    20.12     34.16        21316
                                                      AVG= 47.88                                          AVG= 21654
1983 257 63.07   4    147.00    445.4    74       84       11.88     12.50     421.65     0.00      0.00         4454
1983 257 63.07   5    149.50    445.4    74       79        5.93      6.08     420.31     0.00      0.00         2227
1983 257 63.07   6    152.00    445.4    74       77        3.56      3.61     419.75     0.00      0.00         1336
1983 257 63.07   7    154.50    445.4    74       77        3.56      3.61     419.75     0.00      0.00         1336
1983 257 63.07   8    157.00    445.4    74       77        3.56      3.61     419.75     0.00      0.00         1336
                                                                AVE=  5.88                                AVE=  2138
------------------------------------------------------------------------------------------------------------------------------------
1983 258 63.08   1     13.00    978.2    72       91       40.64     46.01     730.34    20.45     25.56        18586
1983 258 63.08   2     18.00    978.2    72       96       51.44     60.34     732.16    20.51     39.84        23476
1983 258 63.08   3     23.00    978.2    72       94       47.12     54.49     731.45    20.48     34.01        21520
                                                      AVG= 46.40                                          AVG= 21194.
1983 258 63.08   4    147.00    475.4    73.      81.      10.20     10.63     447.16     0.00      0.00         3804.
1983 258 63.08   5    149.50    475.4    73       78        6.36      6.53     446.27     0.00      0.00         2377.
1983 258 63.08   6    152.00    475.4    73.      77.       5.09      5.20     445.97     0.00      0.00         1902.
1983 258 63.08   7    154.50    475.4    73       76        3.81      3.87     445.66     0.00      0.00         1426.
1983 258 63.08   8    157.00    475.4    73.      76.       3.81      3.87     445.66     0.00      0.00         1426.
                                                                AVE=  6.02                                AVE=  2187
------------------------------------------------------------------------------------------------------------------------------------
1983 258 63.09   1     13.00    970.9    72.      92       42.78     48.78     729.66    20.19     28.58        19418.
1983 258 63.09   2     18.00    970.9    72.      96       51.40     60.30     731.10    20.24     40.06        23302.
1983 258 63.09   3     23.00    970.9    72.      93.      44.92     51.57     730.03    20.21     31.37        20389.
                                                      AVG= 46.37                                          AVG= 21036.
1983 258 63.09   4    147.00    469.2    73.      81.      10.38     10.83     452.06     0.00      0.00         3754.
1983 258 63.09   5    149.50    469.2    73.      77.       5.18      5.29     450.84     0.00      0.00         1877.
1983 258 63.09   6    152.00    469.2    73.      76.       3.89      3.95     450.52     0.00      0.00         1408.
1983 258 63.09   7    154.50    469.2    73.      75.       2.59      2.62     450.19     0.00      0.00          938.
1983 258 63.09   8    157.00    469.2    73.      75.       2.59      2.62     450.19     0.00      0.00          938.
                                                                AVE=  5.06                                AVE=  1783.
------------------------------------------------------------------------------------------------------------------------------------

------------------------------------------------------------------------------------------------------------------------------------
DFDD= DISTANCE FROM DISTRIBUTOR PLATE
```

POOR

QUALITY

ORIGINAL